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Spacelab User Interaction

Final Report

IBM

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Final Report

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1. INTRODUCTION

1.1 GENERAL

This final report serves to document the results and findings of a study undertaken to define means of optimizing the Spacelab experiment data system by interactively manipulating the flow of data. This Spacelab User Interaction Study was performed by IBM for the Marshall Space Flight Center (MSFC).

The Spacelab User Interaction Study was initiated by a prior study performed by IBM for MSFC in which a total source to user data flow was defined for Spacelab experiment data. It was recognized during this work that the total volume of data to be generated by Spacelab experiments would far exceed the existing data processing capability. This fact gave reason for initiating a separate study for determining the feasibility of interacting in or near real time with the data to reduce the volume while maintaining the quality of the data.

The interaction study project was organized into three phases. The first two phases have been completed and previously documented. This document presents the results of the third and final phase of the study.

1.2 PHASE I REVIEW

The first phase of the User Interaction Study was intended to define an interactive user interface by presenting interaction implementation concepts. Interim milestones included establishing the need for interaction, developing candidate approaches and concepts, and identifying criteria for the selection of interaction techniques. Figure 1.1-1 illustrates the flow of the Phase I study. The approach was to determine Spacelab payload experiment definitions, evaluate documented data system requirements and constraints, and investigate user requirements in order to qualify the interaction idea.

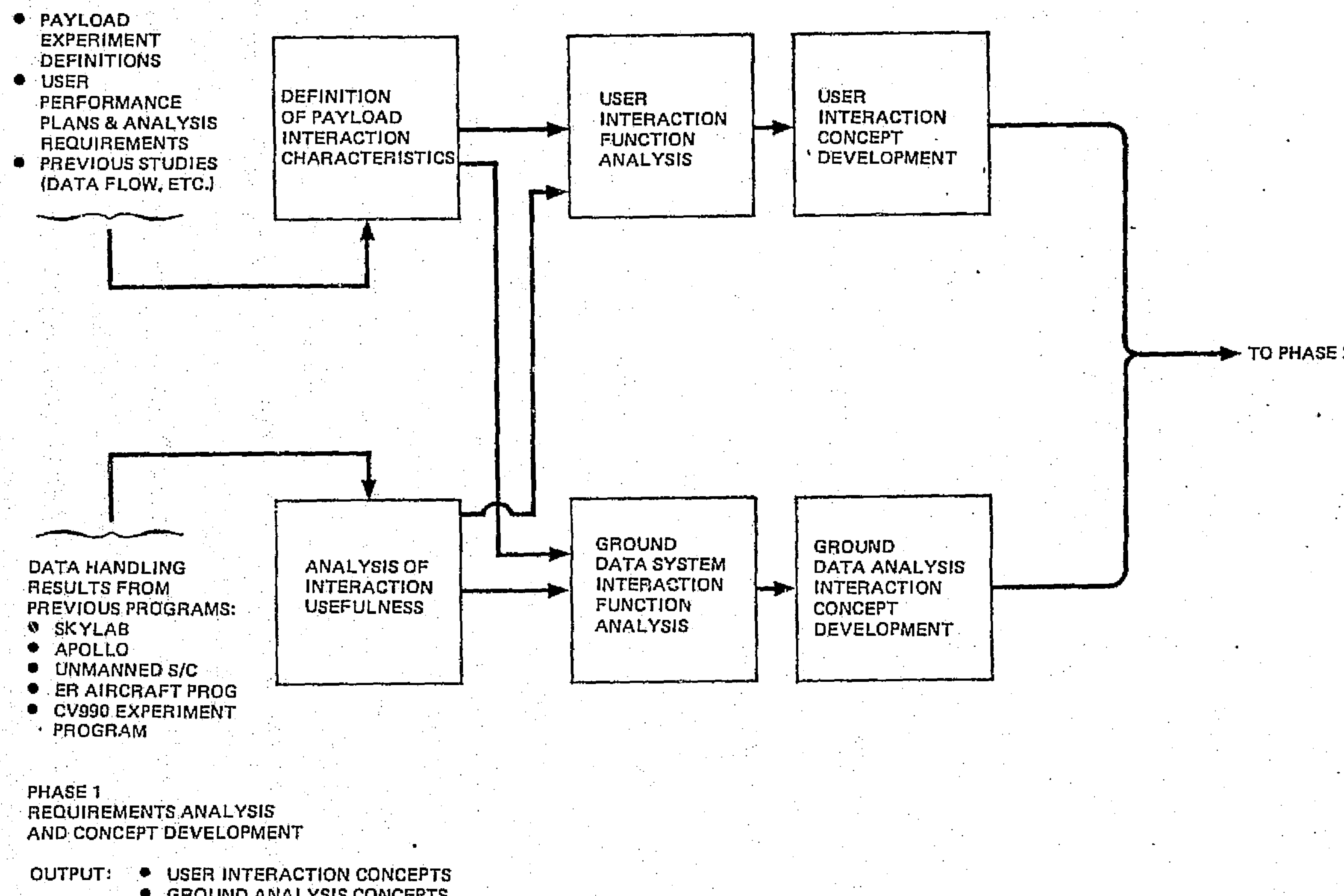

Figure 1.1-1 PHASE I INTERACTION STUDY FLOW

Once the need for interaction was established, concepts were developed for implementation of an interaction system. Various candidate configurations were considered involving onboard versus ground, automated versus man-tended, and software versus hardware options. An interaction system design concept was selected which assumed an onboard experimenter with ground monitor. This system configuration incorporates characteristics of all the candidate options and was used in subsequent study phases as the baseline system design configuration. Figure 1.2-1 depicts the onboard/ground combination system for experiment control.

The Phase I study results were documented as part of the final report for a study entitled "Space Station Data Flow, Amended For: Shuttle/Spacelab Experiment Payloads and Spacelab/Interaction" (IBM No. 74W-00140) and dated May 1974.

1.3 PHASE II REVIEW

Phase II of the study was devoted to the identification and definition of interaction techniques applicable to the Spacelab experiment data flow. A specific approach was adopted which involved the selection of baseline payloads whose associated data flows would serve as a vehicle for the demonstration of interaction techniques. The baseline payloads were selected after having identified interaction amenable sensors and experiments.

The payloads selected as baseline were SO-01-S (Solar Physics) and EO-06-S (Earth Observations). These payloads appeared also to be the data drivers for their respective disciplines. Data flows were drawn for the two payloads and, after having researched the applicable documentation and sampled the available experience references, the interaction techniques were defined. Figure 1.3-1 depicts the flow of the Phase II study and its relationship to Phases I and III.

The end item for the Phase II study was a description of candidate interaction techniques and their application to the baseline data flows. These results were reported in a formal presentation given at MSFC on May 16, 1975, and the accompanying document (IBM No. 75W-00093).

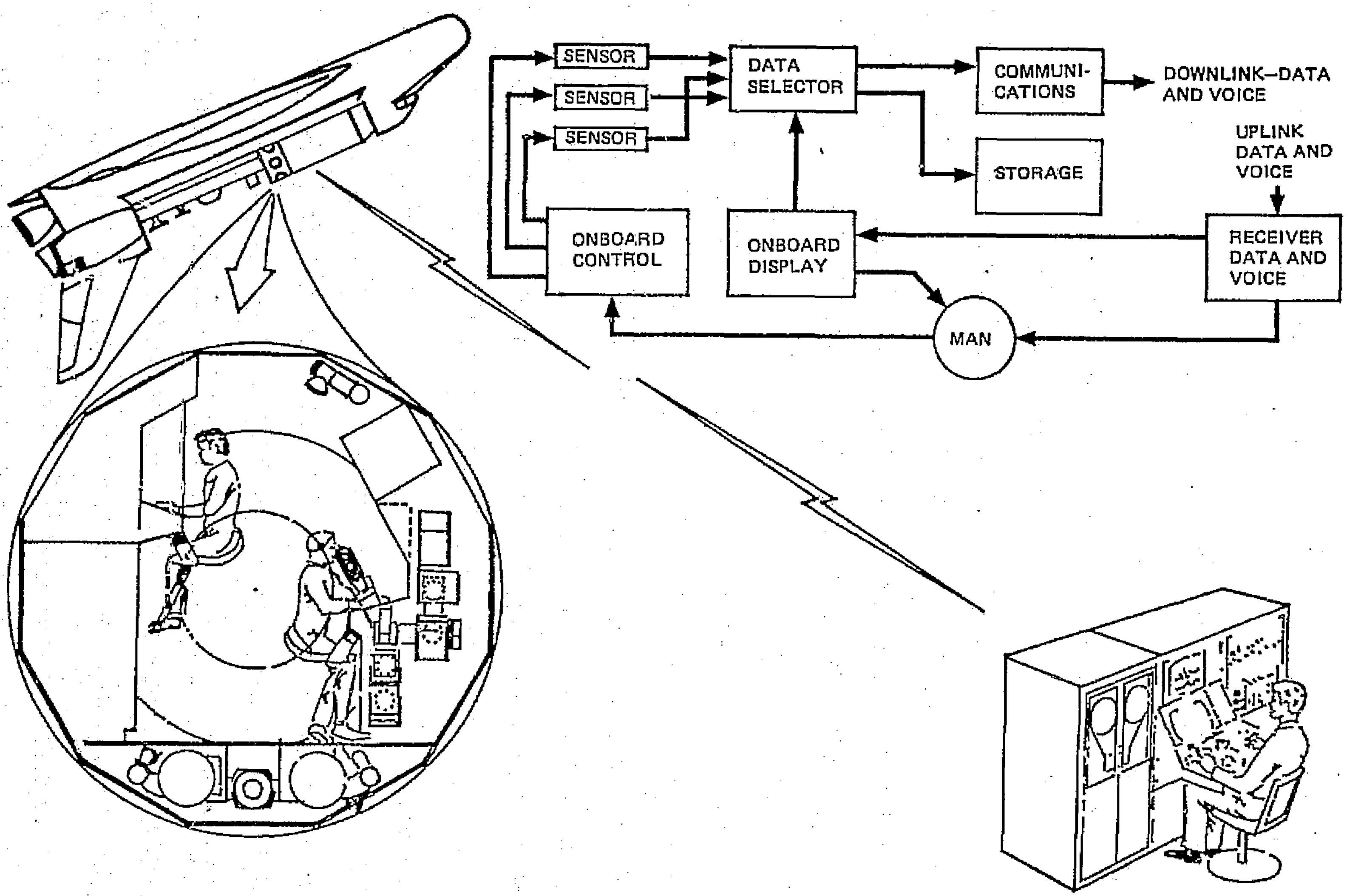

Figure 1.2-1 SELECTED USER INTERACTION CONCEPT

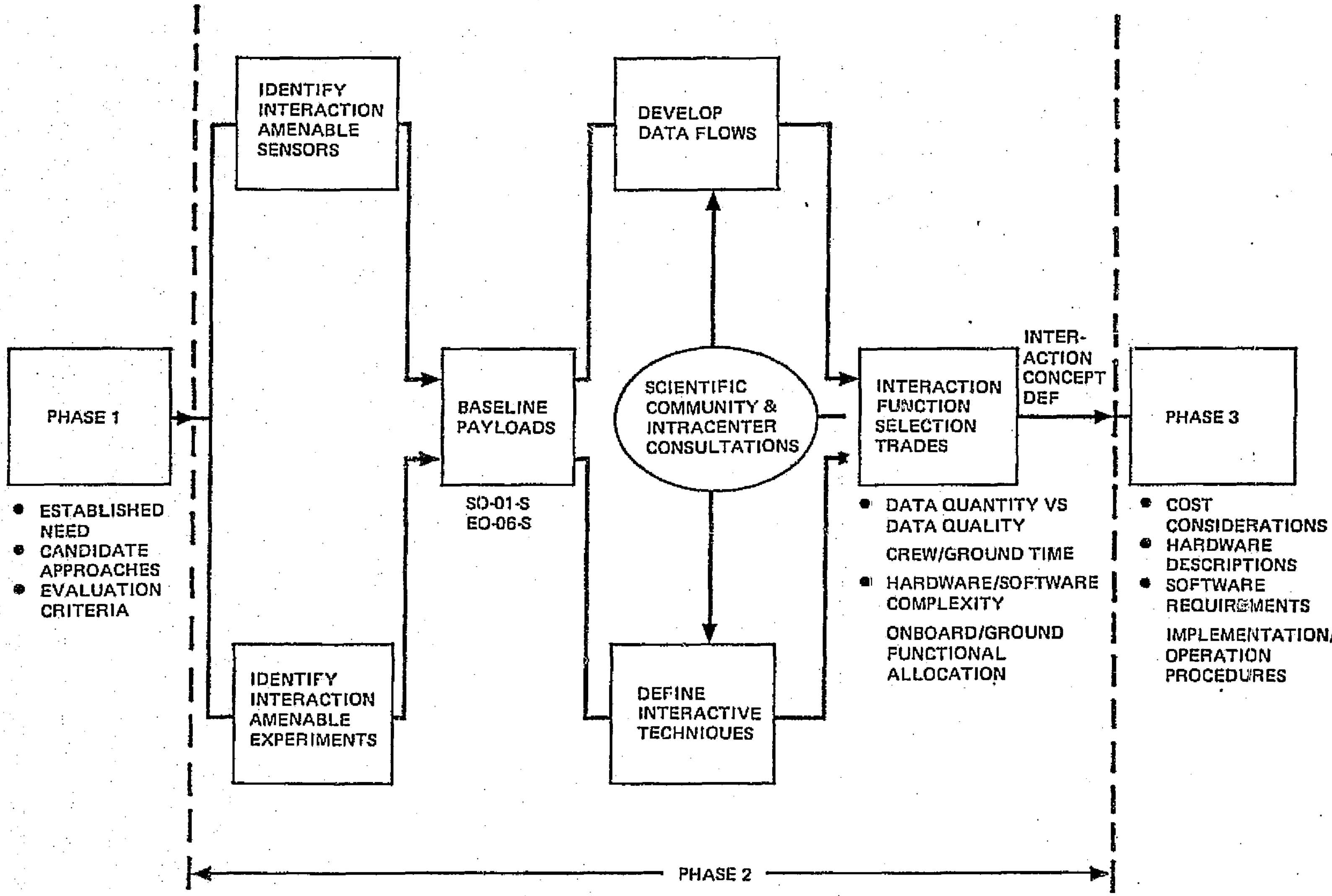

Figure 1.3-1 PHASE II APPROACH

1.4 PHASE III APPROACH

The Phase III task involved consolidating and combining the techniques of interaction identified during the Phase II work into interaction systems for each of the two baseline payloads. Each technique was evaluated for inclusion in the interaction system on the basis of benefit versus cost considerations. Questions of onboard versus ground application and hardware versus software implementation were approached with the intent of providing the most cost effective means of optimizing the data flow.

The remainder of this document serves to present the Phase III task results and also as a final report for the User Interaction Study contract. The two baseline interaction systems are defined in detail complete with functional and operational descriptions, hardware specifications, and software requirements for both onboard and ground based system elements.

2. SUMMARY

2.1 ASSUMPTIONS AND GUIDELINES

In the process of defining and costing the interaction systems for the two baseline payloads, several assumptions and guidelines were necessary. The basic data requirements for each of these payloads were assumed to be as presented in the Level B SSPD dated July, 1974. Any changes adopted were done so only after telephone contact with the appropriate experiment managers.

The interaction systems were designed to be compatible with the CDMS configuration presented in the Payload Accommodation Handbook, dated May, 1975. The existing CDMS facilities were utilized as much as was practical in the system definition work. The baseline CDMS definition was not altered, however, to effect the integration of the interaction system elements into the onboard data system. The interaction system elements are presented as deltas from this baseline CDMS.

While the data management for the EO-06-S payload involved only onboard activities (no data transmitted to ground), the SO-01-S payload also involved ground operations. In the absence of a Payload Operations Center (POC) definition, the ground interaction system elements were presented as requirements. It was assumed that these ground system requirements could reasonably be expected to be accommodated by standard POC elements.

The definition of the interaction system elements was not restricted to hardware state of the art. In particular, the high data generation rates of the payload sensors is beyond present data recording capabilities. The assumption was made that if the affected technologies were projected into the 1980's, then the associated requirements could be accommodated.

2.2 RESULTS AND CONCLUSIONS

The interaction study resulted in the definition of interaction systems for two representative Spacelab payloads and the integration of these systems into the CDMS. These system definitions are supplemented with detailed descriptions of the constituent software and hardware elements, and include operational procedures and cost/benefit analyses. These results serve to demonstrate that given a specific payload definition, an interaction system can be designed to effect a data management scheme that optimizes scientific value of the data and the cost effectiveness of the data system. The conclusion is that the interaction idea has proven to be not only feasible, but practical, and extremely effective in reducing payload data costs.

2.2.1 Technical Results

This study resulted in interaction system definitions for the SO-01-S and EO-06-S payloads. The interaction system for EO-06-S is an onboard system with controls originating from the Payload Specialist Station (PSS). The system is designed to offer the experimenter several options for "screening" the data in real time to select only valid data for retention and processing. The scheme features both automated and manual options which involve man-in-the-loop visibility and controls to various degrees. The system designed for the SO-01-S payload involves both onboard operations controlled from the PSS and ground based operations at the POC. Basically, the system is configured to detect conditions which render the data invalid and eliminate this data prior to processing. Operational mode options enable the experimenter to collect data only during periods of high solar activity of significant scientific interest. Other features include options available to enhance the scientific value of collected data.

A benefits assessment was performed to determine the merit of these interaction systems. The cost benefits for each of the two systems were determined by differencing total systems cost from the estimated reduction in data processing costs. Based upon an 85% reduction in data volume, the EO-06-S payload was estimated to save $1.07 million in data processing costs. Comparison of this figure to the total interaction system cost of $.7 million yields a cost savings for the first mission of $.37 million. A similar assessment for the SO-01-S system is based upon a 55% reduction in data to be processed. The total system cost would be $.6 million while the data processing cost reduction is estimated at $1.2 million. These figures yield a first mission cost savings of $.6 million. For both payloads, all flights subsequent to the first would share the interaction system development cost responsibility and the more repeat missions flown, the greater would be the cost savings per mission.

Not all benefits of interaction are readily quantifiable and, consequently, were not included in the cost benefit calculations. This would include some cost savings due to reductions in data storage, data turn-around, and data archiving costs. Less quantifiable savings will also be realized in the area of increased scientific value of the data. More accurate target identification, greater potential for information extraction, and data retakes which might eliminate repeat flights are some of the benefits attributable to this enhancement of the scientific value.

2.2.2 Data Systems Impact

In the process of pursuing the interaction study, several facts were revealed which relate to elements of the total Spacelab data flow. There appears to be a gross difference between the data volume and speed requirements of some payloads defined in the SSPD and the data flow accommodations of the CDMS. Some such payloads do not include any provision for self-contained computing or recording facilities. It is apparent that either

CDMS must be modified to accommodate higher data rates or the payloads affected must be charged with accommodating their own data processing requirements. In the interest of facilitating a more optimum data flow through interactive controls, consideration should be given to expanding CDMS capabilities. The experimenter should be granted greater visibility of his data in real time through onboard processing.

For those experiments which require real time downlink of the data, much of the interactive activity can be assigned to ground operations. The greater processing facilities and scientific expertise located on the ground make more urgent the need for an efficient and comprehensive data transmission system. Indications are that for some payloads only the full TDRSS system capability and coverage are sufficient to support ground based interaction.

The definition of the Payload Operations Center should consider the requirements for supporting an interactive data flow. Significant computing and memory storage would be necessary. POC facilities should include generous display options for such things as data analysis and image comparisons. Hardware capable of generating hard copies of image data would be necessary. False color processing of image data along with image correction algorithms should also be considered. In general, the POC should offer the experiment manager an interactive processing capability.

2.3 RECOMMENDATIONS

2.3.1 General

The research which was required by the interaction study fostered some suggestions for optimizing the effectiveness of the data system. The most significant of these include:

- Force payload sensor design to consider telemetry and data reduction consequences.

- Develop secondary onboard instrument calibration exercises.

- Make more generous use of early pre-mission simulations of the data flow in the design of data system elements.

- Establish realistic expectations in the scientific/user community as to the "real world" nature of their data.

- User requirements should be more effectively incorporated into experiment definition.

This interaction study has served to qualify the interaction principle as applied to two specific payloads. The potential for cost savings in the data processing area was established. The next step towards interactive Spacelab experiment data systems should be to either demonstrate an interactive system via simulation or to expand the interaction system definition to be more comprehensive as applies to payloads, or both. Whichever option is selected, the Spacelab experiment program of the 1980's can realize very significant cost savings in the area of data processing if interaction is allowed sufficient influence in data systems design.

2.3.2 Demonstration

If the alternative is selected to demonstrate interaction via simulation, then a Spacelab payload should be selected which is first, definitely selected for flight on a mission early in the Spacelab series, and second, is amenable to interaction. Once a payload is selected, an interaction system should be designed and integrated into the payload data flow. A demonstration plan should then be written which would include selection of a facility for demonstration. The final step would be to prepare the selected facility and the data systems simulation, and to perform the demonstration itself.

2.3.3 Interaction Systems Applications

The interaction system definitions generated in this study could be used to develop more comprehensive systems. These two sensor systems could each be expanded to apply to all experiments in the payloads. Further expansion would generate interaction systems applicable to all payloads within their respective disciplines. Once systems were designed for each defined discipline, multi-discipline payloads could be considered.

In the final analysis, a decision would have to be made whether to generate a single comprehensive interaction system applicable to all payloads or whether to custom design separate interaction systems for each payload. In either case, a division of responsibility between the Spacelab and payloads elements for the interaction systems would be necessary.

3. SO-01-S INTERACTION SYSTEM

3.1 INTRODUCTION

The SO-01-S payload is the Design Reference Mission for the Solar Physics discipline. The payload experiment package consists of a variety of solar viewing instruments and instruments designed to measure and analyze solar energy emissions. The experiment objective is to detect and analyze solar flares and related active phenomena, to study the properties of the solar atmosphere, and to qualify large solar observatory instrumentation technology. The pallet only configuration of the Spacelab will be utilized for this mission.

For the purposes of the derivation and demonstration of specific interaction techniques, one experiment was selected from the payload experiment complement. The photoheliograph was selected from the candidate sensors because it appeared to be both representative of sensor qualities and also the data driver of the set. The photoheliograph generates solar images at high spatial and spectral resolution in ultraviolet, visible, and near-infrared wavelengths. The digitized image data is generated at the rate of 13.4 Mbps. The instrument also generates film data at the rate of 8,000 frames per day; however, film data is not amenable to interaction.

In the absence of interaction, data will apparently be collected from the photoheliograph continuously throughout the seven day mission. The orbiter Ku band 50 Mbit downlink system along with the TDRSS system will be used to transmit the digital data to ground. High speed recorders onboard will buffer the data during periods of TDRSS occultation. Continuous collection of the data would result in approximately 6×10^{12} bits of data to be processed.

The individual interaction techniques developed during the Phase II study were directed towards reducing significantly the amount of data collected and processed. Basically, the various techniques provide a means of: collecting data only during periods of high solar activity; avoiding the collection of useless and degraded data due to the presence of pollutants and equipment failure; enhancing the information to data ratio of the processed data product. The individual techniques have been integrated into the SO-01-S data flow in an attempt to optimize that system. The interaction system includes both onboard elements, controlled from the Payload Specialist Station (PSS), and ground based elements located at the Payload Operations Center (POC).

3.2 INTEGRATED SYSTEMS DEFINITION

The data downlink capability included in the SO-01-S payload definition allows both onboard and ground based interaction with the data. The interaction techniques were evaluated and either eliminated from consideration or integrated into either the onboard or the ground based elements of the interaction system. The onboard elements of the interaction system are integrated into the existing definition of the Spacelab CDMS. The onboard interaction elements will be presented as a delta from the baseline CDMS configuration depicted in Figure 3.1-1. The ground operational center, the POC, is essentially undefined and, hence, the ground based elements are presented as a system requirement and not as a delta from a POC system.

3.2.1 Technique Evaluation

Each of the techniques of interaction developed during Phase II of the study were evaluated and analyzed on the basis of benefit versus cost, ground versus onboard application, and software versus hardware implementation. The following paragraphs contain a brief evaluation of each of these techniques.

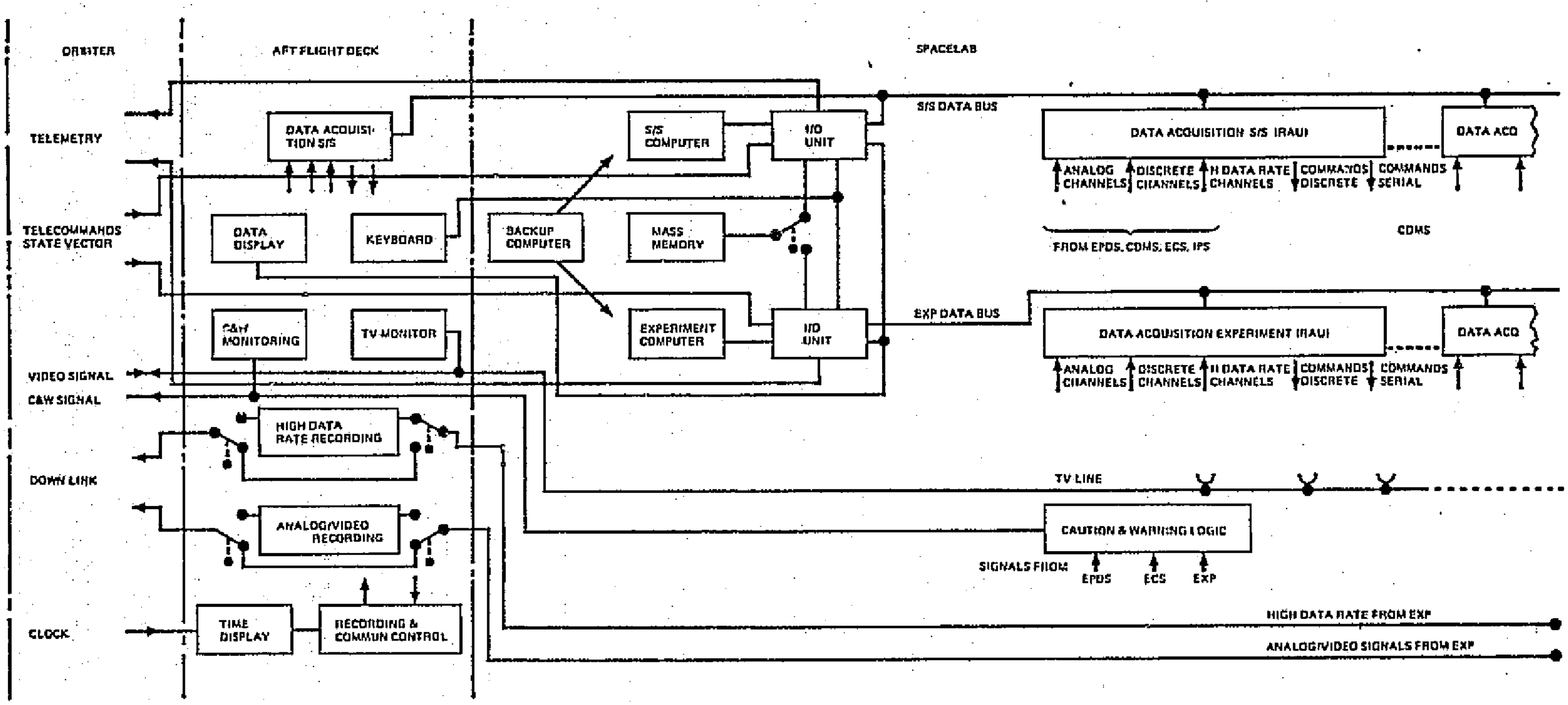

Figure 3.1-1 FUNCTIONAL CDMS BLOCK DIAGRAM FOR PALLET ONLY MODE (BASELINE)

The Operational Status Monitor was defined to monitor preselected engineering parameters in order to afford early detection of sensor failure. This technique was assigned to the ground system and combined with a scientific data monitor to support an operational status console. There did not appear to be any particular advantage to onboard application and the ground offered more abundant processing facilities. The scheme is effected with a software tolerance test driving a display console.

An Onboard Navigation Scheme was included to determine orbital intervals during which the sensor view of the sun is occulted by the earth. This scheme was located onboard due to the relative simplicity of implementation since all required inputs were available onboard. The scheme lended itself to full automation, which appeared desirable to our various information contacts.

A Radiation Monitor was developed to detect excessive radiation levels which render the photoheliograph data invalid. The scheme was included in the onboard system in order to fully automate the procedure. A hardware radiation detector and a software tolerance test were required for implementation.

A Scientific Data Monitor was defined to monitor selected scientific parameters for an indication of degraded data. The scheme was assigned to ground processing because the high rate of scientific data generation would have necessitated a sampling hardware device for onboard application. A further advantage of ground application was the combination of the technique with the Operational Status Monitor to support a status monitor console at the POC.

A Solar Flare Detection scheme was devised so that photoheliograph data collection could be keyed to the occurrance of solar flares. This technique was originally intended for onboard application, but the CCD

packages and the image comparator would have been very expensive and difficult to interface into the CDMS. Instead, the technique was assigned to ground application to be done with software in near real time. The excessive scientific data generation rate and limited computer storage capability prohibited onboard application of the software configuration.

A technique for Wrap Around Recording was devised as an alternative to full time data transmission. The "wrap around" recorder would retain a 15 minute history of sensor data to supplement occasional periods of full transmission. The scheme is effected onboard with a magnetic tape recorder operated in the wrap around mode and a switch for routing the data. The technique is manageable from onboard or the ground via the command system.

A scheme was proposed for the Detection of Data Pollutants such as noise, gimbal jitter, and control instability. This technique was eliminated due to the difficulty anticipated in detecting and measuring the pollutants. Hardware gimbal jitter and control instability appear to be very difficult to detect and the expected savings would not warrant the expense of hardware modifications and/or additions. Instrument noise should be corrected by routine calibration exercises.

Monitor Sensor Outputs was a technique designed to monitor outputs from selected sensors in the experiment complement for an indication of solar activity. The data taken from the photoheliograph could then be managed according to the level of solar activity. The Grid-Collimeter Acquisition Photometer, the X-Ray Burst Detector, the Gamma Ray Spectrometer, and the Modulation Collimator would be candidate sensors for monitoring. The logic for monitoring these low data rate sensors would be relatively uncomplicated and could easily be accommodated by the onboard computer. The software tolerance test would be applied onboard in real time and would drive either an alert or energy emission measure.

The Data Recall System was devised to provide the experimenter with a capability to do image comparisons for the purpose of target identification and the identification of repeat or duplicate data. The scheme would require very significant storage capability for maintaining a library of reference images. Also the full data stream from the photoheliograph would have to be monitored. These requirements dictate that the scheme be implemented on the ground based facilities. Support software and display hardware along with a hard copy hardware device would be required.

A Change Detection Scheme was originally intended to be implemented into the onboard system but the hardware and interface requirements proved both difficult and expensive. The scheme was devised to generate difference images from any two input images. These difference images contain scientific information which is more readily extractable. This technique will be assigned to ground operations where its software and hardware (display and hard copy) requirements can be met. These requirements are similar to those for the Flare Detection scheme and the Change Detection scheme could easily be integrated into that system.

Software Data Editing is a technique intended to reduce data processing costs by eliminating certain classes of data known to be invalid. By design, the technique is ground based to filter the telemetered data prior to processing into a user product. The software algorithms would be written to eliminate all zero, all ones, saturation data, etc.

The Planned Data Rate Reductions technique was a result of scientists suggestions that the data collection rates might be reduced at some point into a mission when the scientist has established confidence in the integrity of the data system. Implementation would require a software routine for monitoring and displaying preselected parameters. Near real time operation is acceptable and since the experiment principal investigator would likely be located on the ground, the technique was assigned to ground operations.

The Field of View Monitor technique was suggested in response to some scientists expressed desire to observe the sensor field of view in the same wavelength in which the sensor data is generated. Also a similar monitor in the visible wavelengths would expedite pointing exercises and target identification. The transformation elements necessary to obtain visible images from non-visible wavelength instruments proved expensive and impractical. Also, the photoheliograph generates data in the ultra-violet, near-infrared, and visible wavelengths, and includes a camera for field of view monitoring in the visible wavelength. Hence, for this application, the Field of View Monitor technique appeared unnecessary. However, for other payload applications, the technique is recommended for consideration.

3.2.2 Functional Description

The technique evaluations discussed in the previous section resulted in each technique being effected with either hardware or software and being applied either onboard or on the ground. The various techniques were then integrated into an onboard interaction system or a ground based interaction system. The total interaction system is composed of onboard and ground based operations, each of which involves a consolidation of the previously developed techniques. The hardware and software elements of the onboard and ground based interaction systems will be discussed in detail in Sections 3.3 and 3.4, respectively.

The onboard interaction system consists of a combination of hardware and software elements designed to make available to the experimenter options for eliminating useless and degraded data, and transmitting only data of significant scientific interest. The experiment manager will be given the option of transmitting data continuously via the telemetry downlink or to allow full transmission of data only occasionally as dictated by targets of interest. The data collection and transmission mode will be selectable via commands originating at either the onboard or ground based control console.

If the full transmission mode is selected, the data is continuously downlinked via TDRSS. If the choice is reduced transmission volume, then the sensor data is routed onto a "wrap around" or "loop" recorder. This method of recording continues until either the full transmission mode is selected or a target of interest warrants saving the existing data on the loop recorder and initiating a controlled period of full transmission. This part of the onboard interaction system utilizes the control and display facilities at the PSS and is integrated into the Spacelab CDMS.

The data transmission will be halted regardless of operational modes whenever dictated by automated schemes designed to detect excessive radiation levels and sensor field of view occultation by Earth/atmosphere. A software navigation scheme will determine sensor occultation periods based upon data obtained from the orbiter. Discrete outputs will be issued to control the data transmission switches. Another software algorithm will monitor the output of a hardware radiation detector. This tolerance test will also automatically control the data transmission switches in response to radiation levels. Both of these automated routines will feature a manual override capability.

Still another software routine will be included to monitor other sensors in the payload for an indication of solar activity. This routine will drive alerts and/or displays to inform the crew/ground of solar activity status.

Integration of these functions into the CDMS requires the software algorithms and new hardware consisting of the radiation detector and the loop recorder. The CDMS TV lines will be used to route the sensor FOV signal to display consoles at the PSS. Integration of this onboard interaction system into the CDMS is illustrated in Figure 3.2.2-1.

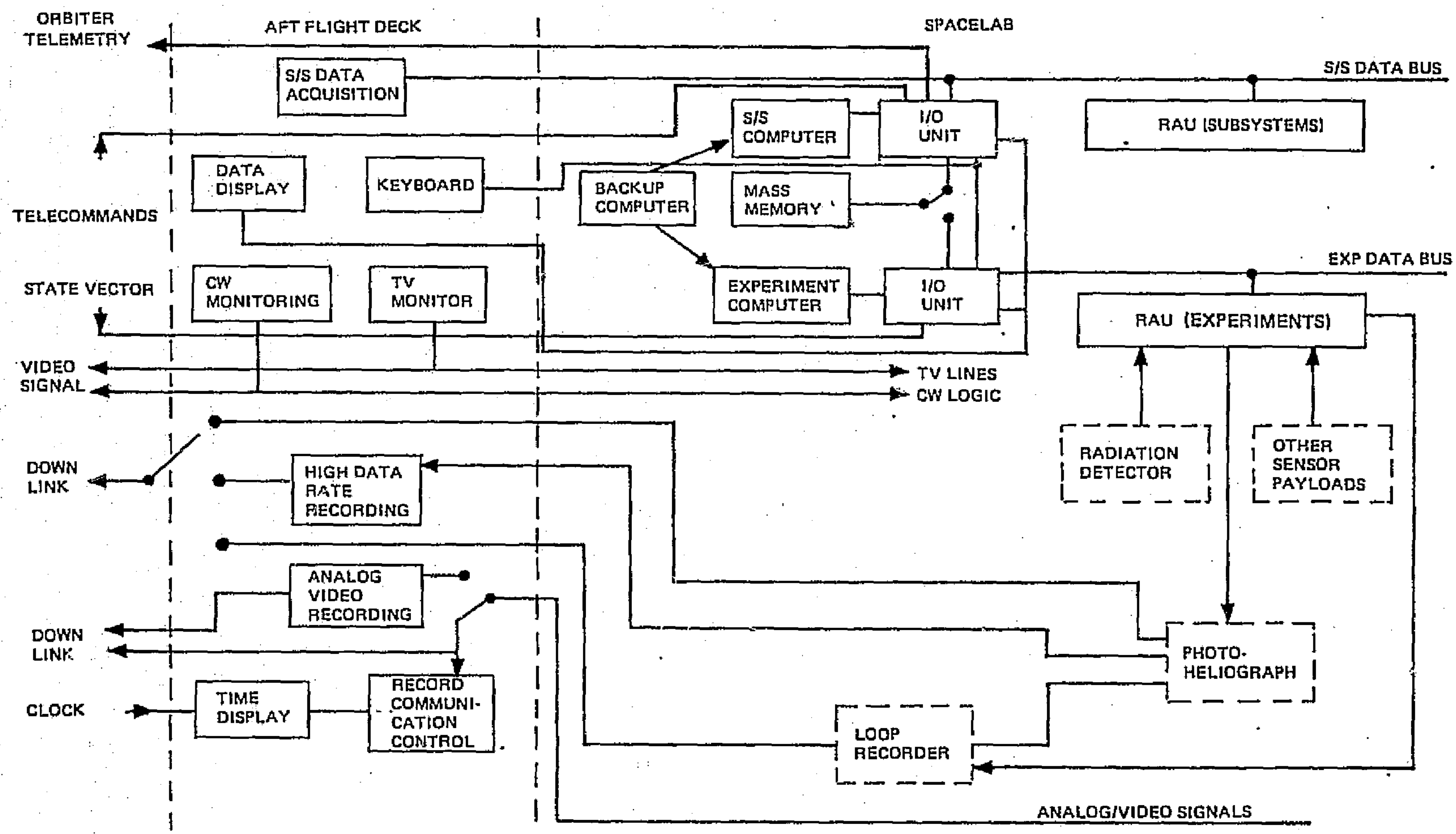

Figure 3.2.2-1 ONBOARD INTEGRATED SYSTEM

The ground based interaction system will require extensive monitoring and processing capability. The system will be designed to operate in near real time to process telemetered data into information necessary for optimizing the total data flow. Extensive computer processing and storage capability complete with keyboard and display support will be required to implement the interaction algorithms. The system will involve the principal investigator or his representative effecting the interaction techniques utilizing facilities resident at a payload operations center (POC). In the absence of an accepted POC definition, the ground interaction system was developed independent of POC facility limitations or restrictions.

The ground system will monitor and process downlinked data from the TDRSS. The interaction will be performed and/or managed from a control and display keyboard and the various interactive options will be selectable from this keyboard. Figure 3.2.2-2 illustrates ground system functions required for Spacelab mission support. All of these functions will be provided by POC personnel except the scientific data manipulation scientist, principal investigator and one (or more) subsystem engineers who would be provided space at the POC for scientific instrument support and science evaluation.

No hardware configuration is implied in Figure 3.2.2-2. Many configurations are possible, and no conflict with interaction requirements would be expected to occur in any specific hardware configuration.

Interactive functions assigned to ground operations are designed to detect potential solar flares, generate difference images of greater scientific utility, monitor sensor operational status, monitor scientific data to validate system performance and to eliminate useless or degraded data from the processing operations. Upon request by the experiment manager, the downlinked data will be processed through a software routine designed to generate difference images from successive input images. The input images may be selected from the real time downlink or from previously loaded magnetic tapes. The difference images created in this manner will be available for display or hard copy. As an extension of this same software package, pixel brightness levels will be monitored in order to identify and

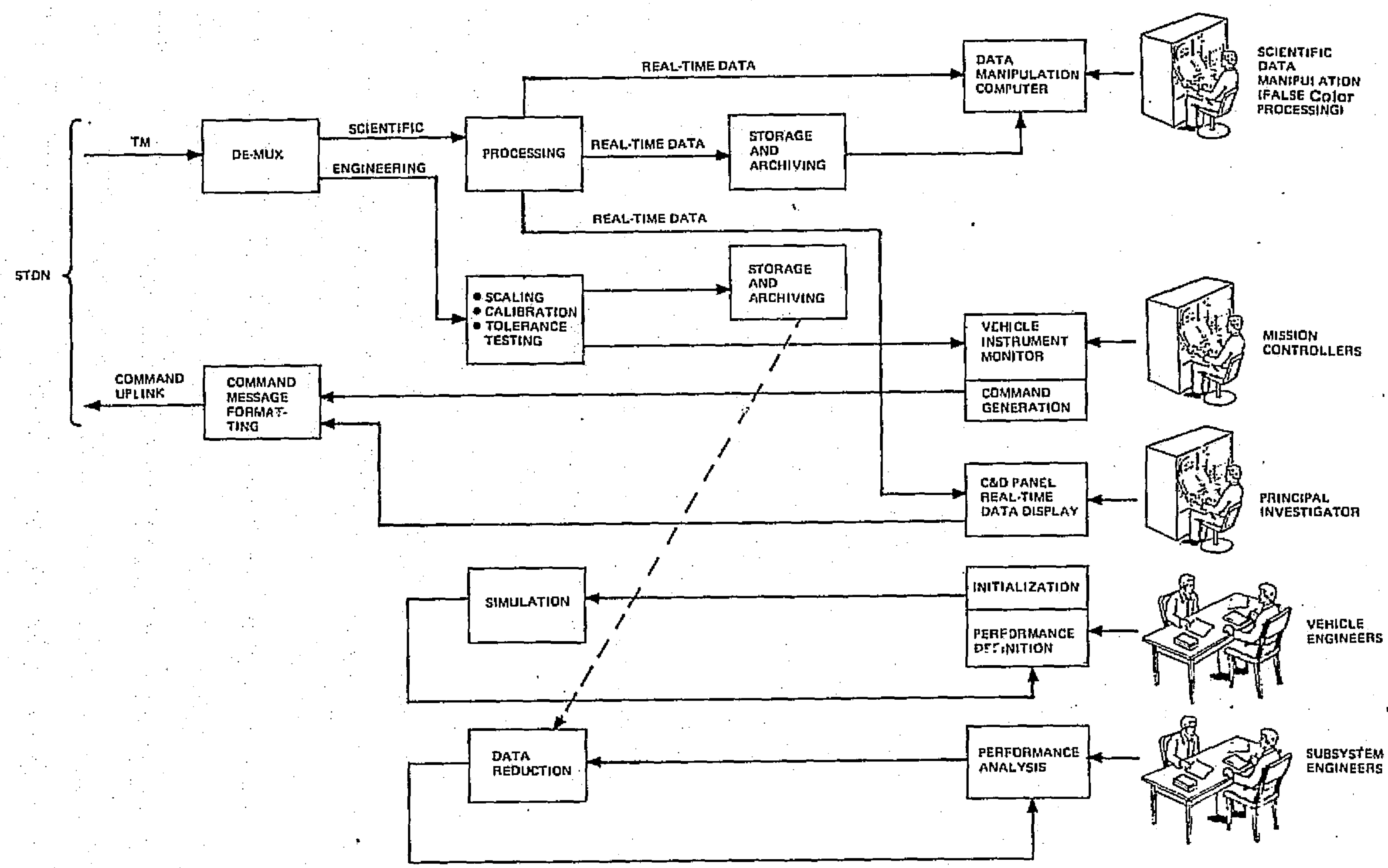

Figure 3.2.2-2 GROUND SYSTEM

monitor the most intense pixels. A tolerance test applied to these pixels would serve to detect potential solar flares.

Another software scheme included in the ground system is designed to support an operational status monitor console. The software is designed to operate continuously on the downlinked data. Preselected scientific and engineering parameters will be subjected to tolerance tests in order to reveal sensor and/or data system anomalies. A similar tolerance test will be applied to downlinked parameters preselected by the experimenter to be indicative of data system validity. Once confidence in the system integrity is established, the principal investigator might consider a reduction in the volume of data to be acquired.

Logic is also available as part of the ground system which will facilitate the recall of previously received or prestored images for comparison to present data. This would be useful for target verification and/or the identification of repeat data. This algorithm will share some of the logic with the image differencing and flare detection algorithms and will require extensive storage capability. Dual displays will be required for simultaneous display of the images for visual comparison. This routine could also be useful in obtaining images for the generation of difference images.

In order to eliminate classes of data known to be invalid, a software algorithm will be applied to all data downlinked prior to processing into a user product. This scheme does not require real time operation. The software tests will check for all zero, all ones, saturation data, etc.

The software and hardware elements required to support these ground based interaction functions will be detailed in the following two sections.

3.3 HARDWARE SPECIFICATIONS

3.3.1 Introduction

Figure 3.3.1-1 illustrates the SO-01-S interaction system, identifying standard CDMS components, payload components, and components required for the selected interaction techniques. Three components are indicated in the latter catagory on the diagram, a radiation detector, 15 minutes auxiliary storage, and a downlink control switching capability. Functional interface connections are indicated between the components.

The hardware configuration chosen permits retention of 15 minutes of preflare data and all flare data including periods of TDRSS blackout. No "double recording" of data is required (transferring data from one recorder to another) in the process of downlinking data, using the selected configuration.

Tape recorder controls assumed for this mechanization are listed in Table 3.3.1-1. Seven controls are required for the auxiliary storage recorder and four are required for the permanent storage recorder. The permanent storage recorder is planned to be located inside the pressurized cabin of the orbiter, permitting hands-on operation. Functions associated with location of desired data for transmission to ground: rewind, playback start and playback stop are indicated as manual functions since automation of data location would increase the complexity of the system significantly. Four functions are indicated for automated mode control: power ON, power OFF, record start, and record stop. No serious impact to the system will occur if these functions are also allocated to manual control. In that case, software allocated to tape recorder control will be used for generating displays to the payload specialist, who will perform the required tape recorder control functions.

Five modes of operation of the data management system have been identified in Table 3.3.1-2. Of these five, the "TDRSS Post-Occult" mode represents an operational duplicate of the "normal" and "flare" modes, depending on whether or not a flare occurred during the occultation.

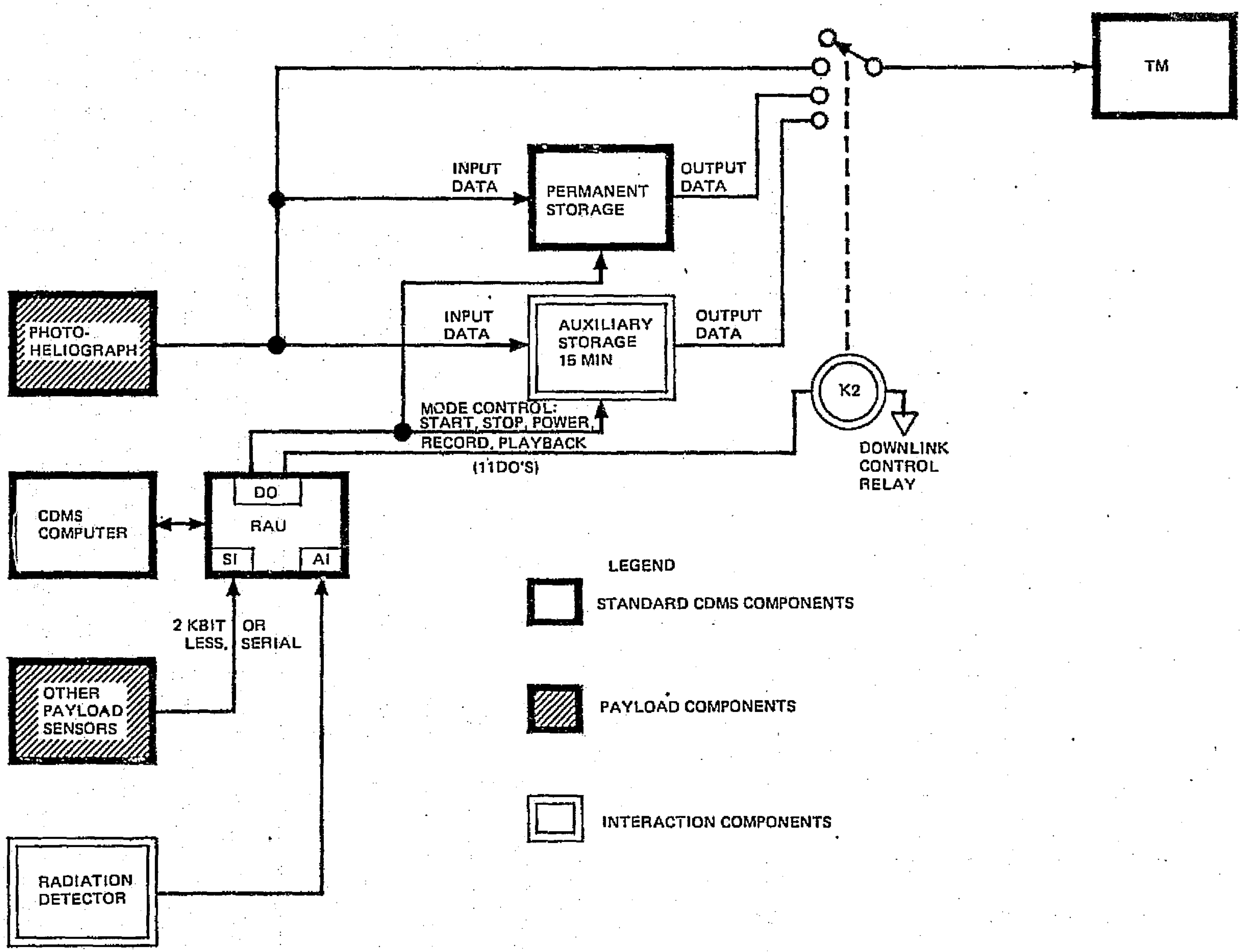

Figure 3.3.1-1 SO-01-S INTERACTION SYSTEM, OVERALL BLOCK DIAGRAM

Table 3.3.1-1 TAPE RECORDER MODE CONTROL

Item	Application: Auxiliary Storage	Application: Permanent Storage	Notes
Power ON	X	X	
Power OFF	X	X	
Record Start	X	X	
Record Stop	X	X	
Playback Start	X	...	Permanent storage recorder is assumed to be designed for "hands-on" operation; redesign for automated operation has not been considered.
Playback Stop	X	...	
Rewind	X	...	

Table 3.3.1-2 DATA MANAGEMENT SYSTEM OPERATION SUMMARY

Mode	Auxiliary Recorder	Permanent Recorder*	Downlink
Normal	Record Photoheliograph	Off	None
Flare	Off	Off	Photoheliograph
Post-Flare	Playback	Record Photoheliograph	Auxiliary Recorder
TDRSS Occulted	Record Photoheliograph	Record Photoheliograph**	None
TDRSS Post-Occult			
No flare in progress	Record Photoheliograph	Off	None
Flare in progress	Off	Off	Photoheliograph

*Required when flare developes while TDRSS is occulted or auxiliary recorder is in playback.
**Upon detection of flare; simultaneously shut off auxiliary recorder.

The period of TDRSS occultation requires special consideration. If a flare (or any other solar activity of interest) occurs during occultation, the permanent recorder must be switched ON to record the activity, and the auxiliary recorder must be switched OFF. This will preserve 15 minutes of sun activity, prior to the observed flare, on the auxiliary recorder, while recording subsequent solar data on the permanent recorder. Following occultation, this data can be downlinked.

3.3.2 Hardware Descriptions and Specifications

Auxiliary Storage Device - A 15 minute "loop" recorder has been specified for the auxiliary storage device. No such recorder exists. However, a functional equivalent can be provided through the use of core, bubble, CCD, etc., memories; or by a standard tape recorder with a reversing capability. Less attractive from a lost-data standpoint would be a standard tape recorder operated in "bursts" of 15 minutes with a tape change or rewind between bursts. From a system standpoint, the auxiliary recorder has three major interfaces (Figure 3.3.1-1).

1. Input data from the photoheliograph consists of a 13.4 Mbit serial stream. Two recorders being developed are candidates for this auxiliary storage device at the present. A GSFC recorder has a design goal of 240 Mbit, but consists of two 120 Mbit recorders operated in parallel. Only a portion of the recorder's 60 tracks would be required for this application, but it is not being designed to reverse, or to operate with a loop of tape. The Spacelab CDMS will provide a 30 Mbit, 28 track recorder. Error rates on both recorders are high 1×10^{-5} and 1×10^{-6}, respectively.

2. Control discretes from the RAU are specified to control the recorder's mode. Eleven discrete outputs can provide this function.

3. Output data from the device is available for downlink telemetry when selected by the downlink control relay.

The RAU mode control will require seven discrete outputs (see Table 3.3.1-1); four additional discrete outputs will be required for permanent storage control.

Radiation Detector - A local radiation sensor (Figure 3.3.1-1) will be utilized to alert the crew of passage through radiation trapped in the earth's magnetic field or being dispersed into the upper atmosphere. Two examples are the South Atlantic Ananomly and nuclear byproducts of atomic explosions. A ± 5 volt analog output is required for compatibility with the RAU and intended interactive usage.

Downlink Control Relay - Three devices must be selectable for downlink (Figure 3.3.1-1). The photoheliograph output can be telemetered in real time, the output of the permanent storage tape recorder, or the auxiliary storage tape recorder must be selectable. A fourth position is indicated for the downlink control switch; functionally this position (no TM input) can be mechanized by programming the Spacelab TM System to omit the scientific data sampling or transmission.

Mechanization of the downlink switching will require four discrete outputs from the RAU, three to latching relays for TM input selection, and one "clearing" command to the magnetic latch relays.

3.3.3 System Options

The selection of tape for the storage medium for the auxiliary storage device is largely a matter of economics. The optimistic estimate of CCD or bubble memory cost in the 1980 time frame indicates approximately 0.01¢ per bit. The 1.2×10^{10} bits required for 15 minutes worth of storage will cost $1,200,000 plus development cost for this application.

Development cost of CCD or bubble memories will be required since clock rates inside the memory will typically be limited to 250 KHz, requiring custom parallel bit storage designs to accommodate the high input and output bit rates.

Projected power and weight estimates for the CCD and bubble technologies in the 1980 time frame also result in unfavorable trades when compared to tape systems. Typical estimates of power are in the kilowatt range, and weight around 1000 pounds for a 10^{10} bit memory.

3.4 SOFTWARE REQUIREMENTS

3.4.1 Introduction

A computer sizing activity was performed to establish onboard and ground computer requirements for the various interactive techniques proposed for the SO-01-S payload. As such, these sizing requirements expressed in terms of computer memory capacity and processor speed are summarized in Table 3.4-1. A detailed breakdown of the sizing analysis is given in subsections 3.4.4 and 3.4.5 for performing the various functions associated with each technique.

Throughout this exercise, an effort was made to 'delta' the interaction requirements from the existing CDMS as defined in the Spacelab Payload Accommodation Handbook, dated May 1975. This refers to sizing control and monitoring functions as well as the scientific data processing software. Regarding this effort, the following definitions were used:

> Control and Monitoring - Includes those computer functions which are required to properly operate and monitor the payload in addition to communicating with the orbiter.
>
> Scientific Data Processing Software - Includes software routines which operate on sensor outputs peculiar to the proposed techniques.

3.4.2 Sizing Assumptions and Groundrules

General

- The sizings reflected for the onboard processing pertain to the general purpose CDMS computer whose operands are 8, 16, and 32 bits for fixed point operations and 8 + 24 bits for floating point. Ground processing is assumed to be done by a computer similar to an IBM S/370 where each 8 bit byte is addressable.

Table 3.4-1 SO-01-S SOFTWARE SIZING REQUIREMENTS

Techniques	Total Storage (32-Bit Words)	Processor Speed Data Processing (KAPS)	Processor Speed Control & Monitoring (KAPS)
Navigation Scheme	181	1.4	0.143
Radiation Monitor	156	1.3	0.150
Loop Recording Control	371	1.1	0.600
Sensor Monitor	677	4.8	0.480
Change Only Image Production (Flare Detection)	43128	2311.5	N/A
Data Recall	23776	1279.5	N/A
Station Monitor	42881	1541.0	N/A
Monitor and Display Functions	42769	1541.0	N/A
Preprocessing Editing Software	41981	963.1	N/A

- Each onboard interactive technique has been sized as an independent subroutine, called by an executive operating under Spacelab executive control.

- All navigation and attitude update data will be provided to the payload by the Spacelab Pointing and Attitude Control (PAC) subsystem which is updated from the orbiter.

Storage

- Storage sizings are given in terms of the number of instructions and data words required to perform each function or logical block of code. For the onboard system, the total storage is determined by adding half the number of instructions to the number of data words since an instruction is 16 bits long. Data words are used for defining constants and memory storage areas which serve as data buffers. Ground total storage is simply the sum of the instructions and the data words.

Speed

- For onboard control and monitoring functions, one instruction is equal to 1.5 equivalent add operations. Speed requirements for scient. ̃c data processing were determined as a function of the number of instructions required to process logical blocks of code in equivalent add operations. This value varies as a function of the amount of processing to be accomplished. Where not specified, one 16 bit data word is equal to 16 equivalent add operations. Due to the large data rates (13.4 Mbps) at which data is output, a significant amount of buffering on the ground is required. To compensate for accessing I/O devices, a 15% data processing overhead rate is being assumed. In both the onboard and ground data processing, the auxiliary storage devices are assumed to have the capacity to hold extremely large quantities of data; ranging upwards to 10^{10}-32 bit words.

3.4.3 Sizing Procedure

The sizings established for the various techniques resulted from transforming functional requirements of the techniques into programmable functions. These functions were then flowcharted. The flowcharts served as the vehicle for estimating both the instructions and data words. The estimates themselves resulted from three sources; namely, coding recurring sections of some functions, updating existing code, and drawing upon experience in performing similar functions.

3.4.4 Onboard Computer Sizing Analysis

3.4.4.1 Navigation Scheme - This interactive technique monitors vehicle position to determine at what points in orbit the sensor field-of-view (FOV) is occulted by either the Earth or the atmosphere. Software peculiar to this technique must automatically direct the data transmission to an onboard recorder or to the ground. When occultation occurs, all data routing or transmission is halted; otherwise, data is downlinked or permanently recorded. This scheme should be updatable from the ground with a manual override feature. Expected cycle time is once per second and continuous throughout the experiment activation period. Table 3.4.4-1 summarizes the sizing estimates. The required computer speed is shown at the bottom of the table.

3.4.4.2 Radiation Monitor - This interactive technique must access and process radiation data as generated by the radiation detector. This radiation data is compared to pre-established tolerance limits. When these limits are exceeded, all data transmission or recording is halted. Continuous testing throughout the experiment activation period is required, and once the radiation level becomes acceptable again, data transmission or recording is re-initiated. The normal cycle time for this technique is once per second. Table 3.4.4-2 presents the sizing requirements for the radiation monitor.

Table 3.4.4-1 NAVIGATION SCHEME

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Access Vehicle Position and Velocity Parameters and Make Required Calculations	52	10	36
Access Stored Ephem Data and Make Required Calculations	50	5	30
Check Sensor FOV for Occultation	6	2	5
Halt Transmission	6	0	3
Transmit or Record Data	10	2	7
Standard Return Logic	20	0	10
SUBTOTAL	168	39	123
CONTROL AND MONITORING (ORBITER COMMUNICATIONS)			
Assure Instrumentation Control	75	0	38
Provide Filtered Vehicle Rates and Attitude Information	20	10	20
SUBTOTAL	95	10	58
TOTAL	263	49	181

SPEED REQUIREMENTS

DATA PROCESSING:

$$\text{Speed} = \left(\frac{1248}{16} \times 16\right)^{*} = 1.248 \text{ KAPS}$$

plus 15% overhead $\underline{.187}$ KAPS

TOTAL REQUIREMENTS = 1.435 KAPS

CONTROL AND MONITORING

Speed = 95 x 1.5 = 0.143 KAPS

*Total number of data processing bits, assuming 16 equivalent add operations per 16 bit data word.

3.4.4-2 RADIATION MONITOR

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Determine Radiation Level (Access Analog Radiation Value)	15	5	13
Perform Radiation Level Acceptance Test	10	4	9
Set Up to Transmit or Record Data	20	4	14
Halt Transmission or Recording	12	2	8
Standard Return Logic	20	0	10
SUBTOTAL	101	35	86
CONTROL AND MONITORING (ORBITER COMMUNICATIONS)			
Assure Instrumentation Control	100	20	70
SUBTOTAL	100	20	70
TOTAL	201	55	156

SPEED REQUIREMENTS

DATA PROCESSING

Speed $= \left(\frac{1120 \times 16}{16}\right)^{*} =$ 1.120 KAPS

plus 15% overhead .168 KAPS

TOTAL REQUIREMENT 1.288 KAPS

CONTROL AND MONITORING

Speed $= 100 \times 1.5 =$ 0.150 KAPS

*Total number of data processing bits, assuming 16 equivalent add operations per 16 bit data word.

3.4.4.3 Loop Recording Control - Software to facilitate routing data either onto or around the loop recorder is required. This technique should provide for the receipt of onboard or ground signals for issuing command discretes to dump recorded data onto the permanent recorder, downlink it directly, or change transmission mode. Transmission modes are defined as loop recording, permanent recording, and telemetry downlink. The sizing requirements for this technique are given in Table 3.4.4-3.

3.4.4.4 Sensor Monitor - This technique was defined to provide the experimenter with a capability for monitoring solar activity. Two sensors other than the photoheliograph will be used. Sensor data will be available via the RAU for processing and later for transmission to the Payload Specialist Station to alert the crew for transmission mode changes if the solar activity level reaches certain limits. Tolerance limit update capability should be provided as a crew option. Normal cycle time for this technique is once per second throughout the experiment activation period. Table 3.4.4-4 shows the sizing requirements for the sensor monitor.

3.4.5 <u>Ground Computer Sizing Analysis</u>

3.4.5.1 Change Only Image Production (Flare Detection) - This interactive technique consists of two phases; one to generate changes or differences in any two downlinked images, and the other to identify and isolate a solar flare. The differenced images of the first phase should be generated for near real time display and also for hard copying at the experimenter's request. The final output medium of this phase should be an ultra-high density (UHD) tape containing only the differenced images.

Second phase processing involves examining successive frames of image data to check for significant brightness levels of individual pixels. This examination or screening process continues until the brightest 100 pixels within each frame are identified. By comparing these 100 pixels to pre-established tolerance limits, possible flares are identified. When a

Table 3.4.4-3 LOOP RECORDER CONTROL

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Determine Transmission or Recording Mode	20	5	15
Set Up to Either Transmit or Record Data	20	4	14
Standard Return Logic	20	0	10
SUBTOTAL	84	29	71
CONTROL AND MONITORING (ORBITER COMMUNICATIONS)			
Assure Instrumentation Control	150	40	115
Perform Image Motion Compensation	250	60	185
SUBTOTAL	400	100	300
TOTAL	484	129	371

SPEED REQUIREMENTS

DATA PROCESSING

Speed $= \left(\frac{928 \times 16}{16}\right)^{*}$ = 0.928 KAPS

plus 15% overhead .139 KAPS

TOTAL REQUIREMENT 1.067 KAPS

CONTROL AND MONITORING

Speed = 400 x 1.5 = 0.600 KAPS

*Total number of data processing bits, assuming 16 equivalent add operations per 16 bit data word.

Table 3.4.4-4 SENSOR MONITOR

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Access and/or Retrieve Engr. and Scientific Data for Sensor "X" and Sensor "Y" via RAU (Assumed to be Analog)	20	10	20
Perform Required Data Conversion	200	20	120
Process Data to Determine Solar Activity Level	50	10	35
Preprocess Data for Display	60	30	60
Perform Updated Calculations	100	10	60
Display Updated Alphanumeric Solar Activity Data	60	30	60
Standard Return Logic	20	0	10
SUBTOTAL	534	130	397
CONTROL AND MONITORING (ORBITER COMMUNICATIONS)			
Assure Instrumentation Control	200	80	180
Perform Image Motion Compensation	120	40	100
SUBTOTAL	320	120	280
TOTAL	854	250	677

SPEED REQUIREMENTS

DATA PROCESSING

Speed $= \left(\frac{4160 \times 16}{16}\right)^{*} =$ 4.160 KAPS

plus 15% overhead .624 KAPS

TOTAL REQUIREMENT 4.784 KAPS

CONTROL AND MONITORING

Speed = 320 x 1.5 = 0.480 KAPS

*Total number of data processing bits, assuming 16 equivalent add operations per 16 bit data word.

sufficient number of successive flare indications is found, a flare alarm (I/O command) is issued, and a search is made to locate the flaring point. This technique will be exercised in near real time during experiment activation periods as specified by the Principal Investigator. Table 3.4.5-1 summarizes the sizing requirements associated with this technique.

3.4.5.2 Data Recall - The data recall technique will require periodic storage of images of downlinked data as requested by the experimenter. These images will be recalled and compared to current real time data. A minimum of five frames of image data is to be stored. Keyboard accessing of these images is required, in addition to dual displays of the stored and current real time data. Processing of the data reviewed under this technique should also provide for pixel differencing. This technique will only be activated per experimenter selection. Sizing requirements are presented in Table 3.4.5-2.

3.4.5.3 Status Monitor - This interactive technique is used to access and monitor preselected engineering and scientific parameters for determining the operational status of the experiment. Approximately 20 such parameters per second will be compared to their respective tolerance limits. All out-of-tolerance conditions will be displayed for crew inspection. Tolerance limits are updatable from the display keyboard. The status monitor technique is exercised continuously throughout the data gathering phase and in real time. Table 3.4.5-3 shows the sizing requirements for this technique.

3.4.5.4 Monitor and Display Functions - This technique involves accessing and displaying key parameters upon keyboard request. These parameters will be selected by the experimenter to check the integrity of the image data. Data will be checked with regard to its generation, acquisition, and transmission. These functions can be performed in real time or non-real time from any previously created data tape. The sizing requirements are shown in Table 3.4.5-4.

Table 3.4.5-1 CHANGE ONLY IMAGE PRODUCTION (FLARE DETECTION)

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (32 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	11	18	29
Prepare Data for Aux Storage	20	4	24
Create 13.4 MBPS U.H.D. Tape	12	2	14
Prep Data for Real Time Analysis (Data Will Pass Thru Main Memory of Ground Computer)	300	42000 (1)	42300
Perform Pixel Difference Analysis	48	4	52
Compare & Identify Brightest (100) Pixels	20	4	24
Perform Flare Detection Analysis and Locate Flare Position by Accounting for X, Y Positions	150	20	170
Provide Hardcopy & Printout of Data	20	6	26
Preprocess Data for Display	60	20	80
Transmit Data via IOP for D → A Conversion, Sync, Interlace and Video Display	150	256	406
Standard Return Logic	3	0	3
TOTAL	794	42334	43128

SPEED REQUIREMENTS

$$\text{Speed} = \frac{1.34^{(2)} \times 10^6 \times 48^{(3)}}{32} = 2010.0 \text{ KAPS}$$

plus 15% overhead 301.5 KAPS

TOTAL REQUIREMENT 2311.5 KAPS

(1) Data brought into main memory at 1/10 instrument output rate into approximately 165K of core.

(2) Processing 1/10 of a second's accumulated data every second.

(3) Assuming 48 equivalent add operations for each 32 bit data word processed.

Table 3.4.5-2 DATA RECALL

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	11	18	29
Save Five Frames of Data (This Data is Stored on Some Auxiliary Storage Device; Data is Directed Without Holding it in Main Storage)	20	4	24
Compare Real Time Data to These Five Frames (One at a Time, Having Two Frames of Data in Memory)	32	23190(1)	23222
Output Comparison Results to Tape	12	(Same Core As Above)	12
Preprocess Data for Display	60	20	80
Transmit Data via IOP for D ⟶ A Conversion, Processing and Display	150	256	406
Standard Return Logic	3	0	3
TOTAL	288	23488	23776

SPEED REQUIREMENTS

$$\text{Speed} = \frac{741760^{(2)} \times 48^{(3)}}{32} = 1112.6 \text{ KAPS}$$

plus 15% overhead	166.9 KAPS
TOTAL REQUIREMENT	1279.5 KAPS

(1) Two frames of 46,360 pixels at 8 bits per pixel.

(2) Assuming two frames of pixels are processed each second.

(3) Each 32 bit word processed is assumed equal to 48 equivalent add operations.

Table 3.4.5-3 STATUS MONITOR

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	11	18	29
Retrieve Data from Auxiliary Storage Device	12	41875 (1)	41887
Locate Requested Parameters, Make Required Conversions on Both Scientific & Engr. Data and Provide all Required Preprocessing	500	(Same Core As Above)	500
Provide Software to Support Accessing Tolerance Limits via Keyboard	200	50	250
Compare S&E Parameters to Tolerance Limits	32	10	42
Preprocess Data for Display	60	20	80
Display Out-Of-Tolerance Parameters	60	30	90
Standard Return Logic	3	0	3
TOTAL	878	42003	42881

SPEED REQUIREMENTS

$$\text{Speed} = \frac{1.34 \times 10^{6\,(2)} \times 32^{(3)}}{32} = 1340.0 \text{ KAPS}$$

plus 15% overhead 201.0 KAPS

TOTAL REQUIREMENT 1541.0 KAPS

(1) Data retrieved and brought into approximately 165K core at 1/10 instrument output rate.

(2) Processing 1/10 of a second's accumulated data every second.

(3) Assuming 32 equivalent add operations for each 32 bit data word processed.

Table 3.4.5-4 MONITOR AND DISPLAY FUNCTIONS

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	11	18	29
Retrieve Data from Auxiliary Storage Device	12	41875(1)	41887
Preprocess a "TBD" Set of Parameters for Display (Involving Primarily Conversions and Calculations)	500	(Same Core As Above)	500
Determine Data Generation Status for Data ACQ and Transmission	100	20	120
Provide Hardcopy and Printout of Data	50	10	60
Preprocess Data for Display	60	20	80
Display Data in Alphanumerical Format	60	30	90
Standard Return Logic	3	0	3
TOTAL	796	41973	42769

SPEED REQUIREMENTS

$$\text{Speed} = \frac{1.34 \times 10^{6(1)} \times 32^{(2)}}{32} = 1340.0 \text{ KAPS}$$

plus 15% overhead = 201.0 KAPS

TOTAL REQUIREMENT 1541.0 KAPS

(1) Data fetched at 1/10 instrument output rate into approximately 165K of core.

(2) Processing 1/10 of a second's accumulated data every second.

(3) Assuming 32 equivalent add operations for each 32 bit data word.

3.4.5.5 Preprocessing Editing Software - The purpose of this technique is to identify invalid data and eliminate it from the data processing system at the earliest possible point. Checks will be made for all zeros, all ones, and other masks as identified by the experimenter. This function will be performed post real time at the convenience of the processing center. Table 3.4.5-5 summarizes the sizing requirements.

Table 3.4.5-5 PREPROCESSING EDITING SOFTWARE

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	11	18	29
Retrieve Data from Auxiliary Storage Device	12	41875 (1)	41887
Perform Reasonableness Type Tests on Data Against a Pre-Defined Mask Set by Principal Investigator	40	10	50
Output Acceptable Data onto a Tape (U.H.D.)	12	(Same Core As Large Block Above)	12
Standard Return Logic	3	0	3
TOTAL	78	41903	41981

SPEED REQUIREMENTS

$$\text{Speed} = \frac{1.34 \times 10^{6\,(2)} \times 20^{(3)}}{32} = 837.5 \text{ KAPS}$$

plus 15% overhead = 125.6 KAPS

TOTAL REQUIREMENT 963.1 KAPS

(1) Data fetched at 1/10 instrument output rate into approximately 165K of core.

(2) Processing 1/10 of a second's accumulated data every second.

(3) Assuming 20 equivalent add operations for each 32 bit data word processed.

3.5 OPERATIONAL PROCEDURES

Basically, operation of the SO-01-S interaction system will consist of monitoring sensor and software test outputs and reacting to control the mode of data collection/transmission. The monitoring function will be performed utilizing data and test results displayed at consoles located at the PSS (onboard) and at the POC (ground). The displayed results will then be used to assist in making decisions concerning experiment redirection and data flow mode control. Keyboard controls at the PSS and/or POC will direct the required signals to the onboard data command system.

Two modes of operation will be defined for the SO-01-S interaction system; a "standard" mode for low activity periods and a "data" mode for periods of high solar activity. The interaction system operation may be initiated by the experimenter at any time after the occurrence of experiment activation at approximately ten hours after liftoff. Initially, the data mode for full data transmission should be selected in order to allow ground expertise a cursory look at data for an indication of acceptable systems performance. Once the experiment managers are confident of acceptable initial systems performance as indicated by the ground data monitor, the standard mode of interaction system operation will be initiated.

The standard mode of system operation will involve routing the photoheliograph data to the loop recorder which serves as auxiliary storage for 15 minutes of recorded data. Once this recorder is filled with data, the tape is rewound and data overlay begins. During the playback of this recorder, data will be routed to the permanent recorder. The permanent recorder will also be used to store data during periods of TDRSS occultation. The data held on the permanent recorder will be downlinked at the earliest opportunity. The downlink control relay will be switched automatically to halt data transmission if software tests for sensor FOV occultation or excessive radiation levels dictate. Onboard standard operational procedures will include monitoring the outputs of other payload sensors for target of interest identification. Figure 3.3.1-1 presents an overview of this onboard interaction system.

Standard ground operations will involve the processing of previously collected data as desired by the experiment managers. This would include utilizing the facilities for solar flare detection, difference image generation, and image comparison. Periodic transmission of a series of images will be required during the standard mode of operation to support these capabilities. Monitoring of the operational status console will be an ongoing feature of the ground operations, during both standard and high solar activity modes. If sensor or data system anomalies are detected, interaction system operation will be halted until the anomaly situation is resolved. Another on-going ground interaction activity, which is performed off line, is the software editing of the collected data to eliminate various types of data known to be invalid.

Whenever high solar activity periods are indicated by the various monitoring schemes which characterize the standard mode of operation or at the discretion of the experimenter, the data mode of full transmission may be selected. The mode selection may originate either onboard or from the ground. During this mode, the onboard recorders are off and the data is routed directly from the photoheliograph to the downlink. The data is collected by the ground system and held on high density tapes for subsequent processing. Once the solar activity diminishes to a level prescribed by the experiment manager, a return to the standard mode will be made. Commands for system mode control as well as those for on/off, power up/down, recorder playback, manual overrides for automatic elements, and control of the downlink relay may be initiated by either onboard or ground control. Table 3.3.1-2 contains a summary of the data collection/transmission management system.

In summary, the interaction system is designed to provide tools to the experimenter with which he can status the experiment systems and identify targets of interest. This allows the experimenter to factor human judgment and expertise into the data flow management. He is further afforded tools for controlling the amount of data collected. In this manner, the quality and quantity of data collected is optimized by offering an alternative to continuous full data transmission.

3.6 COST/BENEFITS ANALYSIS

To determine the net impact of implementing the interaction system for a SO-01-S payload mission, a cost versus benefits analysis was performed. Interaction system cost was determined by combining the costs of each individual hardware and software element of the system. Cost benefits were derived by estimating the cost savings incurred with the reduction in the volume of data to be processed. These totals were then compared to generate a cost savings figure.

Software elements of the interaction system were priced by estimating the development cost of each algorithm. The pricing assumed a cost of $20 per instruction for both onboard and ground based elements. This cost per instruction figure has been based upon Skylab and Saturn software development experience. Table 3.6-1 presents a listing of individual algorithm costs.

Hardware element costing assumed that standard laboratory equipment could be used. The only hardware element which would be situated in the space environment of the Spacelab pallet is the radiation detector and the space qualified feature would not significantly increase costs. Table 3.6-2 summarizes the individual hardware element costs. Pricing the auxiliary recorder required projecting the technology since the data rate expected exceeds present recorder capabilities. However, such a recorder is presently under development by RCA Corporation for Goddard Space Flight Center.

Table 3.6-2 HARDWARE COST ESTIMATES

Downlink Control Switch	$10,000
Radiation Detector	10,000
Auxiliary Storage	500,000
TOTAL	$520,000

Table 3.6-1 SOFTWARE COST ESTIMATES

Interactive Techniques	Instructions	Cost ($)
Navigation Scheme	263	5260.00
Radiation Monitor	201	4020.00
Loop Recorder Control	484	9680.00
Sensor Monitor	854	17080.00
Change Only Image Production	794	15880.00
Data Recall	288	5760.00
Status Monitor	878	17560.00
Monitor and Display Functions	796	15920.00
Preprocessing Editing Software	78	1560.00
TOTAL	4636	92720.00

Cost benefits attributable to the interaction system are associated with a reduction in the data processing costs. These data volume reduction savings include a reduction in computer processing, operations personnel, data storage, data turn-around, and data archiving costs. Of these savings areas, only computer processing and operations personnel costs are easily quantifiable. For the purposes of this study, only these two cost areas will be used to determine cost benefits. Table 3.6-3 indicates the data volume reductions estimated for each of the interaction elements for which this benefit is applicable. The figures shown in this table reflect percentages of the total volume of data expected in the absence of interaction activities, i.e., 6×10^{12} bits. This volume reduction translates into 4583 hours of computer processing time which, in turn, represents a cost savings of $1,245,000. These calculations assume 40 instructions per byte of data to be processed and an execution time of one microsecond per instruction. Comparison of this cost benefit figure, to the total cost of $612,720 for the interaction system yields a cost savings figure of $632,280.

Table 3.6-3 DATA VOLUME REDUCTIONS

Navigation Scheme	5%
Radiation Monitor	5%
Loop Recorder (flare only)	30%
Status Monitor	5%
Software Date Editing	10%
TOTAL	55%

In summary, the proposed interaction scheme would result in a data processing cost savings of $632,280 for the first mission flown. Subsequent SO-01-S missions would share the system development cost responsibility and the more repeat missions flown, the greater would be the cost savings per mission. In addition to these cost savings, other data system benefits are a direct consequence of interaction system applications. Increased scientific value of the data can be realized from interaction system elements such as the

flare detection, difference image production and data recall algorithms. In particular, these elements can provide for more accurate target identification and render the data more amenable to information extraction. In all cases, the total savings realized from the interaction system are a function of the PIs concern for data savings which will be reflected in system mode selection and also a function of the level of solar activity.

4. EO-06-S INTERACTION SYSTEM

4.1 INTRODUCTION

EO-06-S is a Spacelab, pallet only, payload. The payload flies only one sensor, a six spectral band Multi-Spectral Scanner (MSS). The MSS is an instrument capable of remotely sensing incident and radiated spectral information from a ground target as it is observed from the orbiting spacecraft. At the present, all data gathered by the MSS is specified to be stored onboard the orbiter via an Ultra-High Density (UHD) magnetic tape recorder supplied with the payload. MSS scientific data generation rate used in this study is 118.5 Mbps (this data rate has been obtained from MSS design and development community contacts), i.e., for each of the six spectral bands it is 19.75 Mbps. The minimum scientific data generated in a seven day mission (31 data take passes x .25 hr/data take pass) is calculated to be on the order of 3.35×10^{12} bits and reasonably may be expected to exceed this with "target of opportunity" sightings, etc.

Since no data is expected to be returned to ground except by the magnetic tapes returned at the end of each mission and since neither the payload nor the Command and Data Management Subsystem (CDMS) offer any more than a nominal evaluation capability of the collected data, a genuine need can be seen for some onboard analysis and evaluation tools capable of assuring confidence in the data quality and capable of assuring satisfaction of mission objectives in a timely manner. This assurance is realized through the means of the described interaction techniques which follow. The fact that CDMS in its very latest configuration can not accommodate or provide these desired tools for this payload will also be discussed in the sections on Hardware/Software Requirements.

The quantity of scientific data generated will be quantitatively reduced by the means of interaction to effect less storage requirements (both onboard and later in archival form), to effect less need for CPU facilities and time for data processing and to effect less need for manual analysis and evaluation time of the data for scientific value and content. The reduction of the data

by means of interaction is designed to maintain and improve data quality via the improved monitoring of the data collection system performance. Integrity of the scientific content or value of the data is maintained throughout the application of any interactive tool or technique.

Interaction for EO-06-S may be generally understood to be implemented in the following manner: (1) By use of "screens" that will be applied to the data in real time (the particular screen or combination of screens to be applied will be determined by the experiment operator in light of the operational environment), and (2) by use of man-in-the-loop visual and judgmental faculties to qualify and further reduce the data quantity by resorting to visual scanning of the data and screening it for significance and quality after (1) above has been performed, i.e., a post-data pass screen is applied.

This study bases its approaches and results on SSPD, Level B (June, 1974 as updated by contacts with the responsible design and development personnel assigned to EO-06-S), Spacelab Payload Accommodation Handbook (May 1975) and Spacelab Instrumentation Handbook (November 1974). The study assumes intent to integrate the EO-06-S payload with CDMS (see CDMS data in SO-01-S Introduction, Figure 3.1-1). Study output addresses the "delta" (addition or changes) to CDMS hardware/software capabilities as presently specified.

Significant baseline data, in brief, for defining the EO-06-S Integrated Interaction System are:

- MSS scientific data generation rate is 118.5 Mbit/sec or 19.75 Mbit/sec for each of six spectral bands of output.

- MSS Field of View (FOV) is 15^{0}, Instantaneous FOV (IFOV) is 66×10^{-6} rad, with picture element resolution @ 12.5 meter (for 185 KM orbital altitude).

- A picture element data word is represented as 8 bit coded gray scale.

- Six-band serial data @ $\approx$ 120 Mbit/sec is stored directly (after multiplexing) on a Ultra-High Density (UHD) Magnetic Tape Recorder that is payload furnished.

- The UHD recorder has rewind and read capability.

- The MSS operation is controlled fully by the CDMS Experiment Computer Operating System (ECOS) via the Data Bus/RAU. The experiment computer maintains navigation and control information for gimbaling the MSS focal plane to correct for vehicle rate and control errors (no MSS independent gimbaling is possible).

- MSS operational status, Caution and Warning (C&W) information is available from the CDMS/ECOS.

- The CDMS Experiment Data Bus provides for high rate digital data (serial) transfer from the experiments with a limit of 500-600 Kbit/sec (exclusive of analog data and discretes). The MSS Remote Acquisition Unit (RAU), however, is more severely limited by permitting $\approx$ 100 Kbit/sec of digital data. No other means of providing real time, high rate digital data from the experiment to the CDMS experiment computer is available.

- The CDMS/ECOS can control display of data (not scenes/images) provided to it via the RAU by the Integrated Interaction System.

4.2 INTEGRATED SYSTEMS DEFINITION

4.2.1 Technique Evaluation

The Phase II Spacelab User Interaction Study Report (May 1975) produced for EO-06-S some twelve techniques that had potential to interactively effect considerable data quality improvements and data quantity savings. The integration of these techniques into a single system with various operationally selectable modes of effecting interaction required an adjustment be made to some of the originally recommended techniques. The use of certain of the techniques became a matter of priorities centering around (1) value of reducing data quantity and enhancing data quality, (2) hardware/software requirements and costs for implementation and (3) practical consideration of difficulty to functionally build and use. The following paragraphs detail the disposition of those techniques.

The Improved Payload Management in the Non-Visible Spectrums is supplied by the Real Time Display provided in each of the Real Time Screens that are functionally described in 4.2.2. Real Time Display of the Spectral Bands or Channels requires input/output processing and interim storage capabilities to condition the high rate scene data for video monitoring. The televised telescopic terrain view is not provided though it may be easily implemented if an Earth viewing telescope flies with the payload.

The Processor for Use of Sampling Techniques is specifically applied to the very desirable goal of doing a brightness histogram or Spectral Condition Detection test on the MSS generated data in real time. The Spectral Condition Detection test is performed on only one channel of MSS data at any given time (see functional description Spectral Condition Detection).

"Quick Looking" Data for System Performance is fully provided for as originally envisioned but is incorporated as a part of each real time screen and is selectable independently during the post data pass period of each orbit.

The System Anomaly Detection Processor is provided for by querying the CDMS experiment computer as to system C&W status. The response will determine the status of a data quality discrete indicator which may in certain instances terminate the data take, initiate self-test logic for fault location or just simply flag data as degraded (bad) in order to expedite ground processing. No provision is made to merge anomalous event data with the scientific data since little onboard image processing can be performed and with ground processing such data would be redundant to the telemetry which has already been downlinked, processed and is available.

The "Quick Look" Screen for the "Frame of Interest" is provided for in the Post Data Pass Screen (see Functional Description) though it is not implemented as originally conceived in Phase II. All benefits originally conceived for this technique are still realizable. The primary difference in the "Post Data Pass Screen" and the "Quick Look" for the "Frame of Interest" is that coding as to quality and utility of the screened data is performed rather than actuating a separate storage function for the resultant screened data. This approach precludes needs for simultaneously buffering six bands of scene data for storage on a secondary recorder, it precludes a second recorder (the onboard hi-data rate recorder would require ≈ a 6:1 ratio of record time to that of the MSS supplied recorder) and minimizes a highly probable wear-out problem with MSS tape recorder start/stop/rewind functions.

Post Pass Critical Analysis Screen for scientific content is available to the extent that onboard CDMS computational and analytical tools can be called up to critique a given scene. No onboard full image processing and data analysis is reasonably possible using CDMS because of the RAU/Data Bus rate limitations and the limited core (which affects time to process a given scene) available in the CDMS.

The technique, A Screen to Record Only When Condition Requirements are Met, is implemented by the real time screen (see Functional Description), Spectral Condition Detection. However, the continuous monitor (or detector) for the given spectral condition can evaluate only one spectral channel to any given

time to determine data acceptability. The technique used does not rely on the continuous loop recorder or separately starting/stopping the final storage recorder; rather the Spectral Condition Detection screen simply annotates the data in real time, on a once per second basis, as to data quality and utility which can accomplish all of the originally intended benefits.

Ground Beacon Control of the Data Take is implemented as described in the Phase II study output.

The Processor for Automated Data Take is implemented as described in the Phase II study output with the additional refinement of preparing the system in advance for the data take. Provision is also made for tape recorder OFF at occasions where MSS Shutdown and Warmup periods overlap for targets in near proximity (timewise) of each other but the data record operation is not continuous.

Provision for Onboard Analytical Tools is implemented by the provision within each real time, automated screen application and the post data pass screen to access computational and plot capability via display keyboard controls. Plot application programs will utilize the onboard CRTs for display. This approach saves the need for a desk calculator with the typically available peripherals. Plot programming is intended to be generalized and simple where data points are keyboard entered or accessed from tape and where $y = f(x)$; $f(x)$ is some polynomial expression $\Sigma a_N X^N$. Coordinate scaling would be specified.

Onboard Correction of Detected Noise is not provided due to the hardware/software complexity and CPU size required for onboard implementation as an independent, automated screen. However, most of the desired benefits are distinctly realizable from the image quality of scene displays (in real time or post data pass) already provided with each of the screens from the integrated systems. More elaborate analysis, if ever required, can be provided in real time via TDRSS network link by downlinking any of the six available MSS spectral bands (max @ 20 Mbps) for the brute force evaluation required in a fourier frequency analysis scheme.

The "Sub-Area" Screen for "Frame of Interest" is not implemented for this payload. This screen still appears to be of considerable value when not restrained by the two difficulties apparent in this payload. The "Sub-Area" Screen for "Frame of Interest" is dependent on a buffer capable of holding a full data frame ($\approx$ 100 Mbits of data) for one channel and being able to, in effect, start/stop/rewind and address the same frame on other tape channels (or buffer up to $\approx$ 600 Mbits of data and address up to all six spectral bands simultaneously) hundreds of times per data tape (state of the art reliability forecasts will not permit this at the present). The other aspect of this technique is that a frame ($\approx$ 5 sec of data) typically represents an area computed to be $\approx$ 40 mi. x 25 mi. It is doubtful that time and skills will permit sufficient sub-sectioning of a frame and still assure enough recognizable, well-referenced Ground Control Points(GCPs) to geometrically, etc. correct the small sub-section that might be stored.

4.2.2 Functional Description

Real Time Screens:

- Spectral Condition Detection - This screen when selected by the experiment operator, will perform automatically as a continuous monitor of the MSS data as it is being generated. The screen is applied to only one spectral band of data. The channel is selected in advance of flight as a true indicator of desirable or undesirable spectral characteristics that the experimenter desires to screen all MSS data against. One second's worth ($\approx$ 20 Mbits) of digitized pixel data representing a scene is evaluated by the screen each second of data generation. Each second of data generated and stored on the UHD magnetic tape is annotated by code (Pass or Fail/Good or Bad) as to whether or not it satisfied the spectral quality density test criteria and acceptable data system C&W conditions. The spectral density test provides for rapid post data pass screening and sorting of all collected data and also provides an expedient means to more rapidly create computer compatible data tapes (CDTs)

during ground processing. Simultaneous to the application of this screen any one of the six spectral bands may be selected at any time for display to examine and visually monitor on a more or less continuing basis the performance of the data collection system for that spectral band. Certain system malfunctions and/or sufficient data degradation provides for timely termination of a bad data take.

- Ground Beacon Control - This screen when selected by the experiment operator performs in response to recognition of a ground signal as it is transmitted from the vicinity of the target that is to be observed. The signal will be directional requiring sensor sighting of the target before data recording operations can commence. When the signal ceases transmission or sighting of the target cannot be maintained, the data record activities will cease. Simultaneous to the application of this screen any one of the six spectral bands may be selected for display to examine and visually monitor on a more or less continuing basis the performance of the data collection system for that spectral band. Certain system malfunctions and/or sufficient data degradations may provide for timely termination of a bad data take by the experiment operator.

- Fully Automated Data Take Controls - This screen makes use of onboard navigation and control parameters that are available from the CDMS experiment computer. When this screen is selected by the experiment operator, these available navigation and control parameters will be utilized to reckon ground track in an as exact a manner as possible. Resultant ground track positional computations will be used to reckon desired target(s) proximity. When the ground track computations indicate a radial proximity, X1 (value is TBD), to the desired target data take READY operations are performed and when ground track computations indicate a radial proximity, X2 ($X_2 \leq X_1$, X_2 value is TBD), to the desired target date take RECORD

operations begin. When ground track computations indicate a departure from the desired target beyond the radial proximity of X2 data take RECORD operations cease and the data collection system may be placed in a READY or OFF category of operation dependent upon proximity to the next scheduled target. Desired targets (say, for a 72 hour period, i.e., 15-20 targets) with respective ground track coordinates will be RF linked to the CDMS computer from mission control. The CDMS computer will maintain a record of targets sighted and will provide a list of targets not visible (obstructed viewing-clouds, haze, night, etc.) or not acquirable (due to system malfunction, C&W indications, etc.). Unacquired or non-visible targets are to be considered for possible rescheduling. With the application of this screen, any one of the six spectral bands may be selected for display to examine and visually monitor, on a more or less continuous basis, the performance of the data collection system for that spectral band. Certain system malfunctions and/or sufficient data degradations may provide for timely termination of a bad data take by the experiment operator.

- <u>Real Time "Quick Look" for MSS Performance</u> - This screen, though selectable, in effect, while operating in any of the automated modes of real time screening of data is also selectable when all data collected is being stored on UHD magnetic tape and no other screens are in effect. Real time, quick looking of MSS data permits a timely scan of data collection system performance on a per channel basis. This is provided for by a manual selection of the desired MSS spectral band/channel to be scanned and subsequently displaying the scene data generated by that channel. Quick look scanning of the scene data in this manner will permit the experiment operator to make the earliest possible evaluation and corrections if necessary to the data collection effort. Display resolution limits permit a horizontal and vertical sampling of data to be performed that facilitates the implementation of the display requirements.

- Post Data Pass Screen - The data stored on the UHD magnetic tape which has been previously subjected to the real time screens will be further examined during the post data pass portion of the orbits. This technique will make a more efficient use of the hardware and software already provided for by the Real Time Interactive Display capability. The stored data will be reviewed and examined as required to provide reasonable and final assurance of the quality and significance of the immediately past data collection efforts. Data display rate is an option of the data evaluator. This technique provides a timely means to assess and take remedial action for bad data taken or to capture additional data on a target or scene of previously unsuspected scientific value.

4.3 HARDWARE SPECIFICATIONS

4.3.1 Introduction

The groundrule for integration of the proposed MSS interaction techniques into the CDMS was to make maximum use of the standard CDMS components. However, speed limitations of these components when compared to the high data rate of the MSS, precluded their use for analysis or display of the scientific data being generated. Special purpose components are specified to provide the capability to handle the real-time scientific data stream. The technology for these components is 1980 technology, although 1980 state-of-the-art hardware has been avoided where possible. That is, the system design has been molded to fit reasonable operational specifications for the hardware, if state-of-the-art operation was not demanded.

Assumptions and definitions used in the development of the hardware configuration are listed below:

(1) Data should be tagged as good or bad in approximately one second intervals on the tape recorder. This technique is used to identify data that has been determined not to meet the spectral requirements of the data tape. Ideally, this data would be eliminated from the data recorded for later ground processing, but the extremely high data rate of the instrument, 118.5 Mbits, imposes too strenuous a requirement on data collection, interim storage, and subsequent recording to permit deletion of data. Instead, all data is recorded and tagged; ground processing of the unsuitable data can then be eliminated, based on the data "quality" tag. Implementation of the one second criteria is probably best mechanized in terms of approximately one second's worth of instrument scan lines, instead of on a strict time basis.

(2) Data is generated by the MSS in a 4000 pixel per line resolution. The scan rate is adjusted to give approximately the same "vertical" resolution. For video display, sampling of the data to produce a

666 pixel per scan, 525 line image, will produce an acceptable image. This resolution results from a 1:6 data sample for each line, and selection of one out of six scans. The selection process has been designed to produce a video display with approximately the same resolution as commercial television, while reducing the data rate to a range manageable with computers.

(3) Video images are required in all six spectral bands produced by the MSS. Only one band at a time is utilized to produce an image; therefore, a channel selector must be provided to select the band desired for the video display.

(4) Spectral density and quality analysis can be performed using a single MSS band. This band has arbitrarily been designated as #1 in this section.

(5) Use of the CDMS computer for the spectral density and quality analysis would require sampling channel #1 at a 1:200 rate to slow the data down to within the computer processing capability. The analysis "granularity" produced by this sampling rate is not acceptable for on-board, real-time, interaction and dictates the addition of a separate MEDI computer (medium size dedicated processor) for this function. Sampling of channel #1 can be performed at a 1:10 rate utilizing a 1980 MEDI computer, a 20 to 1 improvement over the CDMS computer.

(6) Real-time displays of spectral density and quality analysis are required. This function has been allocated to the CDMS computer. In addition, the CDMS computer has been allocated Caution and Warning activity for the payload, image motion compensation computations and control and automation of all instrument control functions assignable to the CDMS. Instrument design has not progressed to the point

where automated features can be identified. As a minimum, power control to the scan mechanism and instrument would be expected, with possible additions of thermal control, internal redundancy control, filter selection (polarizing, neutral, clear, etc.) and other as yet undefined operational features might be added. The standard CDMS hardware (computer, data bus, RAU, display system) will be utilized for instrument automation.

(7) Post-data-pass analysis of collected data is required to review the suitability of the data for its intended use.

(8) Auxiliary memory will be provided by a developing technology. The requirement exists in this application for a fast, large, easily accessible memory for interim storage of the scientific data prior to spectral density/quality analysis and video display. Bubble and CCD technologies are candidates for this storage medium.

4.3.2 Hardware Descriptions and Specifications

Figure 4.3-1 illustrates the hardware required for the implementation of EO-06-S interactive techniques. Interfaces to the standard CDMS components, and to the payload components are indicated. Although the actual MSS data rate is 118.5 Mbits, 120 Mbits has been used throughout the hardware analysis for convenience. Thus, an individual channel data rate is listed at 20 Mbits instead of 19.75 Mbits.

Table 4.3-1 lists the major hardware items which must be supplied in addition to the standard CDMS equipment. Signal interfaces, brief descriptions, and applications of the six equipment items are listed. Further descriptions of the equipment are provided in the following paragraphs:

Microprocessor #1 - Figure 4.3-2 illustrates the functions that must be performed in microprocessor #1. Real-time data generated by the MSS is stored by this computer into the auxiliary memory. Channel #1 of the MSS,

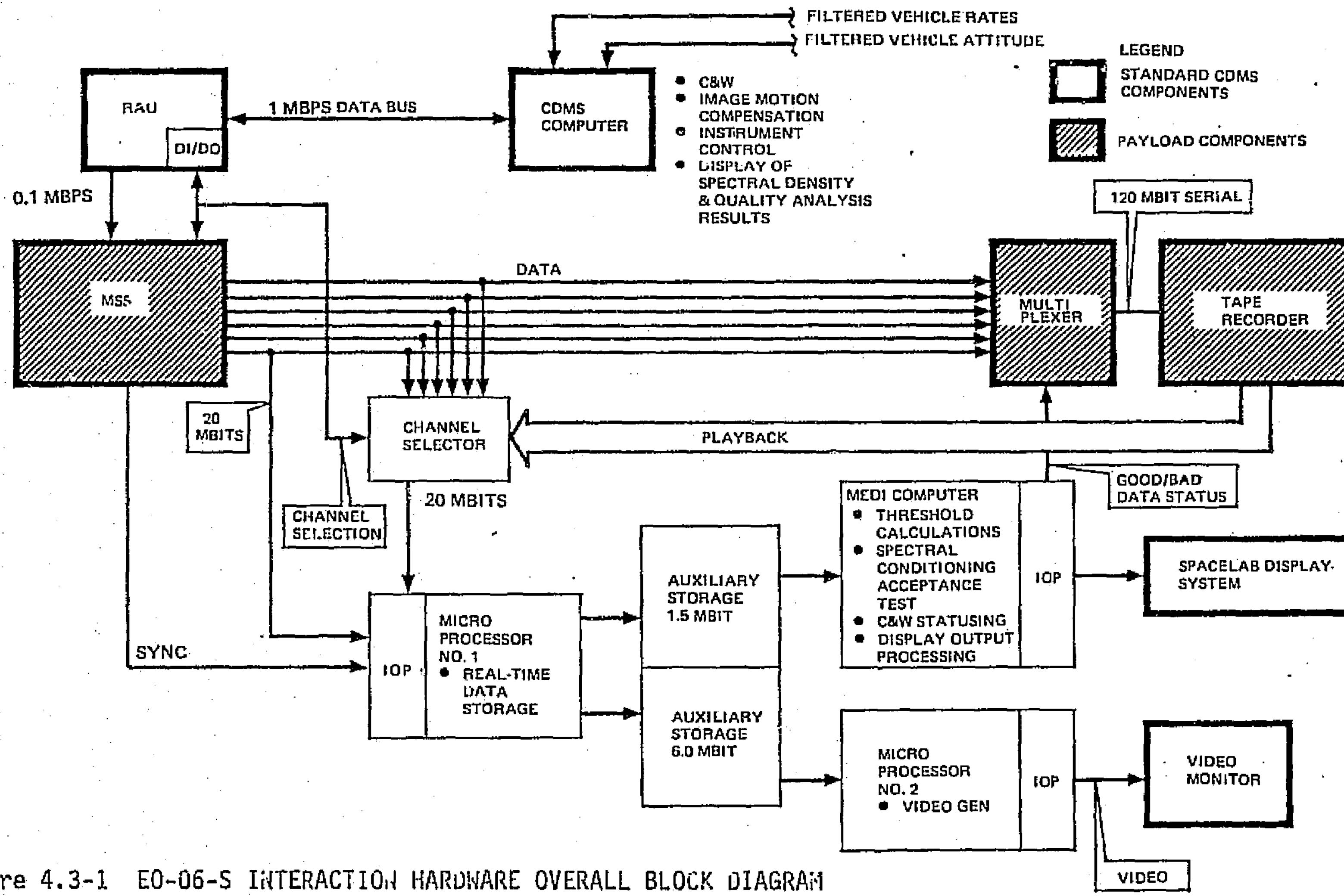

Figure 4.3-1 EO-06-S INTERACTION HARDWARE OVERALL BLOCK DIAGRAM

Table 4.3-1 EO-06-S MAJOR INTERACTION HARDWARE

Item	Application	Description	Signal Interfaces
Microprocessor #1	Real-time data storage	10 usec cycle time, 1K working memory; 2 high speed (20 MBIT) input data channels; 2 high speed data output channels	MSS, channel selector auxiliary memory
Microprocessor #2	Video display generator	2 usec cycle time; 1K bytes working memory; 1 high speed input data channel; multiple D/A converters, synchronization generator EIA standard RS170 video output	Auxiliary memory, CRT
Medi Computer	Spectral density and quality analysis, display support	500 nsec cycle time; 16K bytes working memory; serial output channel; one 8-bit parallel output channel; one 8-bit parallel input channel	Auxiliary memory; multiplexer; RAU
Multiplexer	Combines MSS channel outputs and good/bad data status into a serial data stream compatible with tape recorder input	Six 20-MBIT serial data inputs; 1-slow speed serial data input; one 120-MBIT serial data output	MSS, Medi Computer, tape recorder
Channel Selector	Selects desired input (1 of 6 MSS channels or recorded data) for processing	Six 20-MBIT serial data inputs; one tape recorder input; one 3-bit channel selection input; one 20-MBIT serial data input	MSS, tape recorder, microprocessor #1, RAU
Auxiliary Storage	Temporary storage of real-time scientific data for onboard processing	7.5 MBIT total storage; two 80-bit parallel data inputs; one 160-bit parallel data output; one 16-bit parallel data output	Microprocessor #1, microprocessor #2, Medi computer

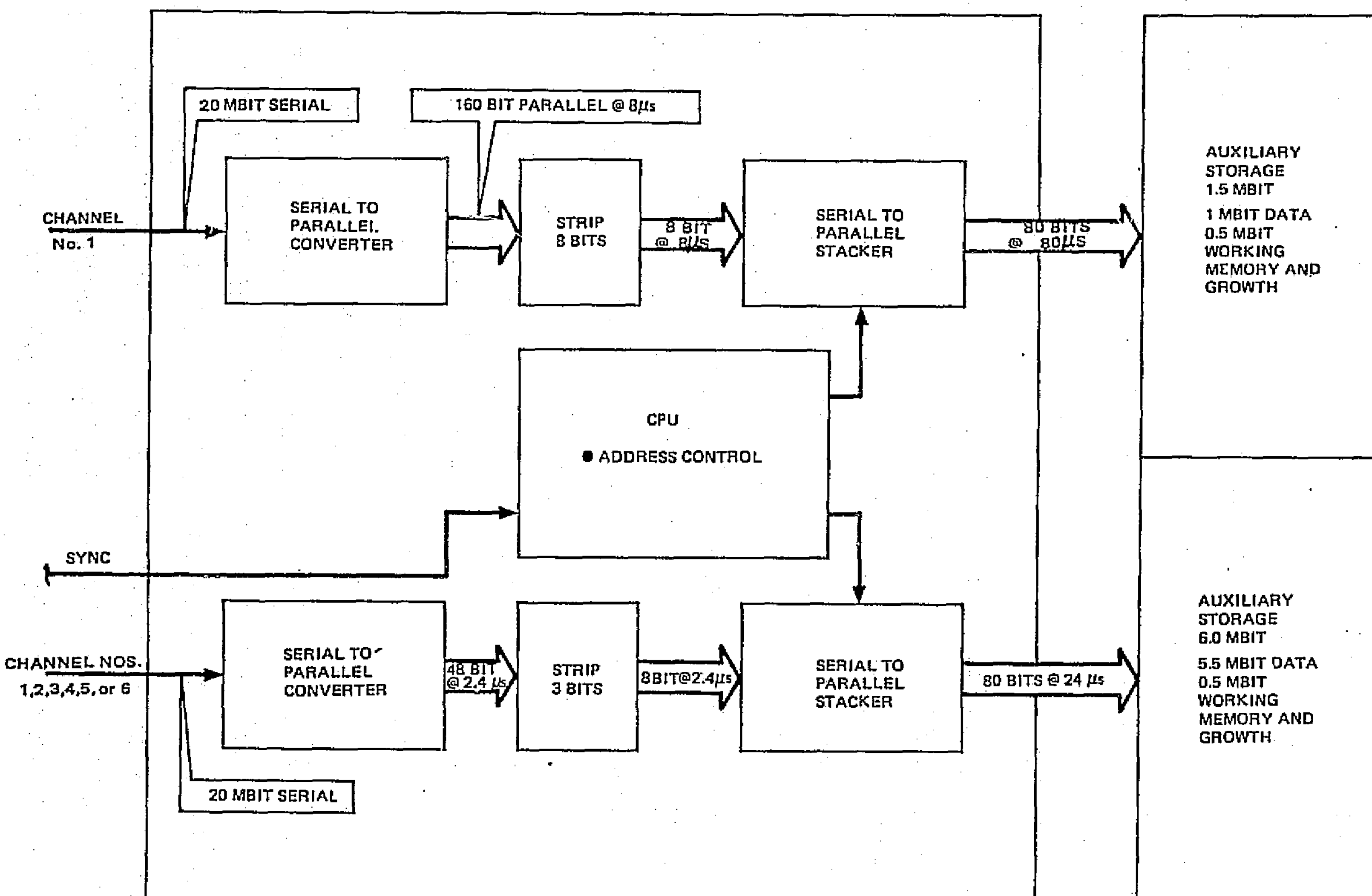

Figure 4.3-2 MICROPROCESSOR #1, FUNCTIONAL DIAGRAM

a 20 Mbit serial data stream, is used for spectral density and quality calculations. The IOP portion of microprocessor #1 converts this serial data stream to a 160 bit parallel format, of which 8 bits are stripped out and the rest discarded. These 8 bits represent one pixel of data and will be obtained each 8 microseconds.

Ten pixels are accumulated in the stacker before being stored in the auxiliary storage. Address control is supplied by the CPU to route the data into the proper location in memory.

Two developing memory technologies, CCDs and bubble memories, are particularly suitable to parallel input data formats; however, monolithic or core memories could also be organized for parallel data inputs.

The serial data stream selected by the channel selector for display to the onboard payload specialist is applied to a similar set of IOP hardware as was described above. Initial serial to parallel conversion in this case is selected to be 48 bits, 6 pixels. Eight of these bits are stripped out and applied to a stacker each 2.4 microseconds, the remaining bits are discarded. The stacker accumulates 80 bits in 24 microseconds, and under CPU control, stores them away in auxiliary storage. Synchronization with the instrument is required to permit organized storage of the serial data stream by lines and frames.

Microprocessor #2 - A functional description of microprocessor #2 is illustrated in figure 4.3-3. Data stored in auxiliary storage by microprocessor #1 is extracted and processed to form a video signal for display. Data extraction in 160 bit (20 pixel) blocks each 2 microseconds will permit CPU functions of organization and data routing to be accomplished with realizable CPU speeds. Four functions are required of the CPU processing:

(1) Data must be sorted into lines and frames according to a predetermined pattern in auxiliary storage.

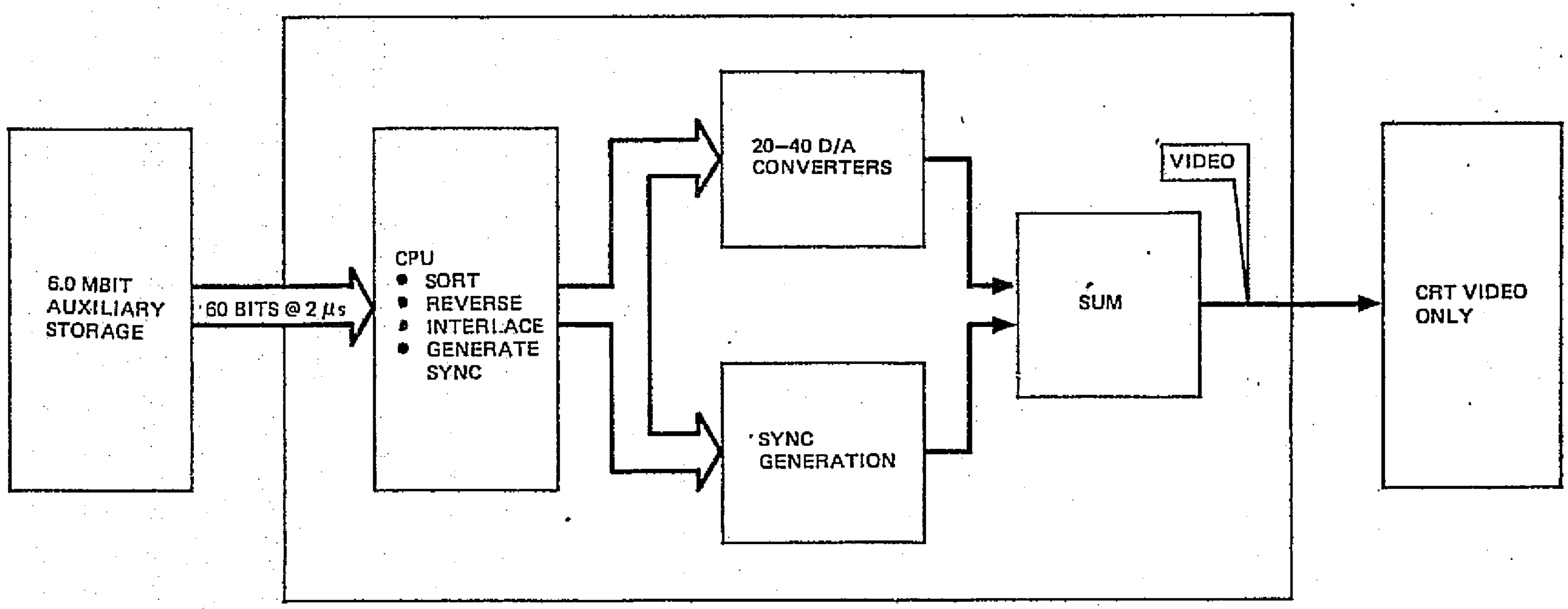

Figure 4.3-3 MICROPROCESSOR #2, FUNCTIONAL DIAGRAM

(2) Every other line must be reversed since the scanning action of the MSS is alternately left-to-right and right-to-left. While the video display is always left-to-right.

(3) Interlacing of the video is required for display; this function can logically be combined with scan reversing. Thus the first half-frame will be "unreversed" data followed by a second half-frame of reversed data interleaved line for line with the first half-frame.

(4) Sync must be generated for insertion onto the video stream.

Multiple D/A converters will be required to create a video luminance signal from the digital data stream. Since data is being moved to 20 pixel blocks, a group of 20 converters would allow simultaneous loading for conversion. Since an essentially continuous data stream is required, a second set of 20 converters would allow the conversion process and setting of the outputs to occur in one set (during a two microsecond time period) while the outputs of the second set are being gated onto the video stream. The sync signal must be summed with the luminance signal to produce the video for display.

MEDI Computer - Scientific data processing and display functions will be performed by the MEDI computer, Figure 4.3-4. Data from channel #1 of the MSS is stored into auxiliary memory by minicomputer #1; retrieval of the stored data and processing to determine acceptability for its intended scientific use is performed by this medium size computer. Communication to the onboard payload specialist through CDMS components (RAU, computer, display) will provide the means for human interaction. Sizing of the software load indicates a high-speed CPU will be required, one with an equivalent add time of less than 500 nsec. Although this represents an extremely fast capability, 1980 technology is expected to be able to provide this capability without severe cost penalty.

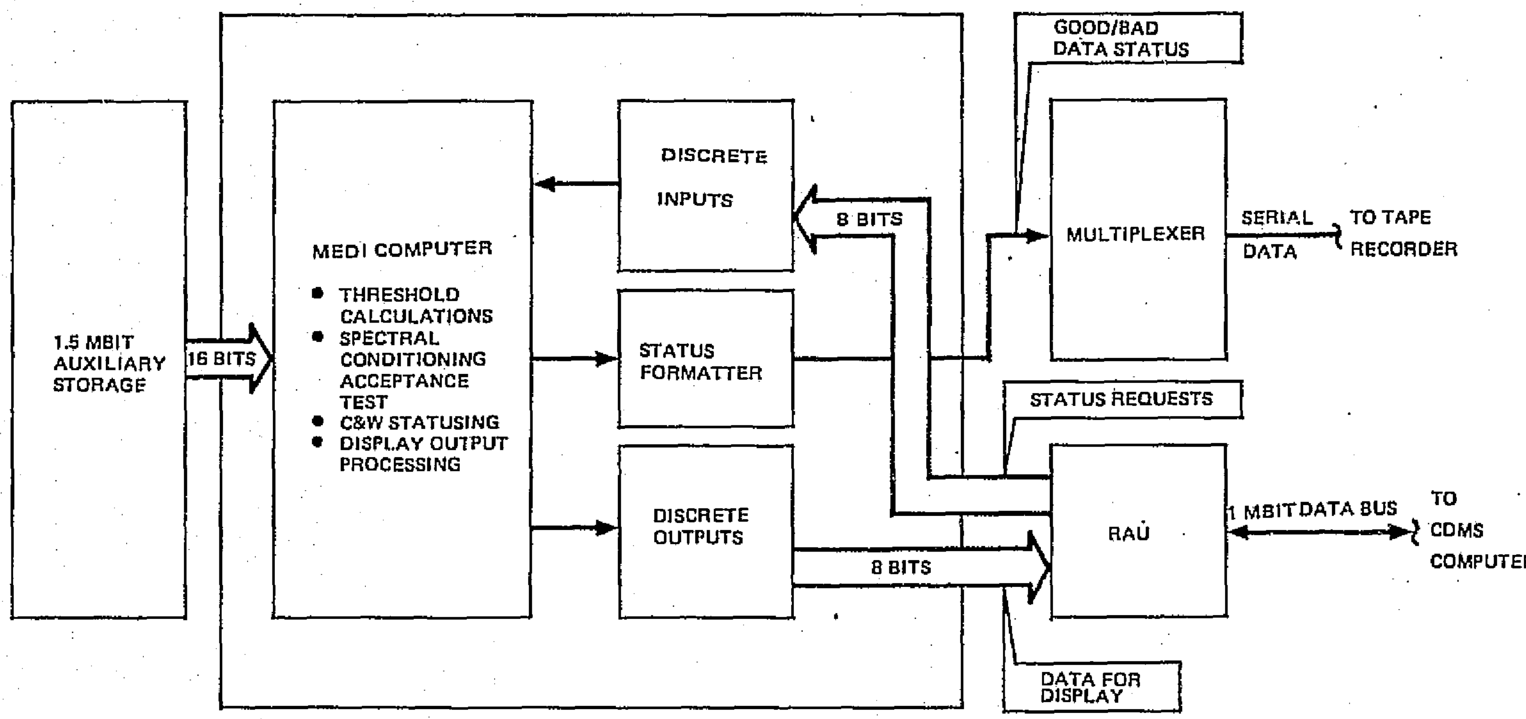

Figure 4.3-4 MEDI COMPUTER, FUNCTIONAL DIAGRAM

CDMS display capability is provided by 8 bit parallel paths into and out of the medi computer. A serial data path to the multiplexer will produce the good/bad indication to be recorded following each one second (approximately) block of data being analyzed.

Multiplexer - The high speed tape recorder being developed by GSFC is the only recorder available for data recording from high speed instruments such as the MSS. This recorder accepts a 120 Mbit serial data stream for recording. Since the MSS output consists of six 20 Mbit streams plus the good/bad data status signal, an incompatibility exists. The payload design must supply a multiplexer to produce a 120 Mbit data stream from the six 20 Mbit streams. The interaction system's good/bad status signal, if accommodated into the original multiplexer design, would be little or no impact on the cost of this item since the data rate involved is so low. The method and format of the good/bad indication has not been selected at this time.

Channel Selector - The channel selector (figure 4.3-1) performs two functions:

- Selection of one of the six 20 Mbit MSS output channels for video generation
- Creation of a microprocessor compatible signal from the tape recorder during data playback

Mechanization of the first function is straightforward and requires switching of one of the MSS outputs to microprocessor #1. Three discrete outputs from the RAU will perform the switching in response to a CDMS display system (keyboard) input.

Tape recorder signal handling at present represents an unknown addition to the channel selection capability, since the recorder output format is undefined. At best, a single channel will be available from the tape recorder and can be switch selected using the same three RAU discrete outputs utilized for MSS channel selection; at worst, a single channel will have to be demultiplexed from the total tape recorder output.

Auxiliary Storage - A total of 7.5 Mbits of auxiliary storage is required for the interaction procedures defined for EO-06-S. This storage falls into two separate categories (figure 4.3-1). Storage for data quality processing will require approximately 1.5 Mbits, 1 Mbit for data storage and 0.5 Mbit for miscellaneous working code and growth. Video generation memory has been sized at 6.0 Mbits. Of this amount, 5.5 Mbits is required for storage of two "frames" of video data. This allows data for one image to be used for image refreshing while the second image is being "built" from the real-time data stream. As before, 0.5 Mbits is defined for working memory and growth.

A discussion of memory technologies applicable for this storage is provided under the SO-01-S hardware section.

4.4 SOFTWARE REQUIREMENTS

4.4.1 Introduction

This sizing activity was concerned with establishing onboard sizing requirements for the proposed EO-06-S interactive techniques. As with the sizing requirements for the SO-01-S payload, estimates are given in terms of computer memory capacity and processor speed. Table 4.4-1 summarizes the results of this effort. Subsection 4.4.3 provides the detailed breakdown of the onboard processing functions for each individual technique.

Every effort was made to "delta" the EO-06-S onboard interaction requirements from the existing CDMS; however, due to the large data rates, it was necessary to sample the data and assume that additional computer support would be available. This additional support is explained in the previous "Hardware Specification" section (see Figures 4.3-1 thru 4.3-4).

4.4.2 Assumptions and Groundrules

The same basic assumptions and estimation procedures used for the SO-01-S payload apply to the techniques proposed for EO-06-S. In summary these are:

- Utilization of the general purpose CDMS computer whose operands are 8, 16 and 32 bits for fixed point operations and 32 bits for floating point.

- Each technique is represented as an independent subroutine, called by an executive under Spacelab executive control.

- Navigation and attitude data is provided to the payload by the PAC subsystem which is updated from the orbiter.

Table 4.4-1 EO-06-S SOFTWARE SIZING REQUIREMENTS

Techniques	Total Storage (32 Bit Words)	Processor Speed Data Processing (KAPS)	Processor Speed Control & Monitoring (KAPS)
Spectral Condition Detection	4364	2300	0.398
Ground Beacon Control	4063	1150	0.518
Fully Automated Data Take Controls	4236	1725	0.555
Real Time "Quick Look" of Unscreened Channel Performance	3800	1150	N/A
Post Data Pass	4800	2300	0.150

- Total storage is determined by adding half of the number of instructions to the number of data words.

- Processor speed for control and monitoring functions is determined by letting one instruction equal 1.5 equivalent add operations.

- Speed requirements for scientific data processing are determined as the number of instructions required to process logical blocks of code in equivalent add operations. For data processing functions concerning just simple tests and tape generation, 16 equivalent adds per 16 bit data word are assumed.

- A 15% data processing overhead rate is used.

4.4.3 Computer Sizing Analysis

4.4.3.1 Spectral Condition Detection - This interactive technique was proposed to determine the spectral quality for a scene of digitized data. Spectral quality and density checks involve processing the image data for video and alphanumeric display, making pixel threshold calculations, and recording quality status of the data on ultra-high density tapes for later analysis. This technique will be selected by the experimenter, and will operate continuously until deactivation or end of experimental period. Table 4.4.3-1 summarizes the sizing analysis for both storage and speed requirements.

Table 4.4.3-1 SPECTRAL CONDITION DETECTION

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Prep and Route Data to 120 MBPS Tape	40	10	30
Prep Data for 1.5 Mbit Auxiliary Storage	20	10	20
Prep Data for 6.0 Mbit Auxiliary Storage	30	10	25
Access 1.5 Mbit Auxiliary Storage with MEDI Computer	20	3200*	3210
Perform Pixel Threshold Calc.	32	6	22
Perform Spectral Conditioning Calculations	10	2	7
Preprocess Data for Displaying	60	20	50
Evaluate C&W Status	50	10	35
Write Data Acceptance Code on Tape	20	4	14
Transmit Data to IOP D $\longrightarrow$ A Converter, Process, Sync, Interlace & Display Video Images	150	256	331
Transmit Data via RAU to CDMS Computer and Display Alpha-numeric Data	60	30	60
Provide Plot Capability on Image Data	400	120	320
Standard Return Logic	20	0	10
SUBTOTAL	936	3698	4166

*Approximately 10 fetches per second assuming MEDI computer has 16K of memory.

Table 4.4.3-1 SPECTRAL CONDITION DETECTION (Continued)

CONTROL AND MONITORING (ORBITER COMMUNICATIONS)

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Provide Caution and Warning Software Interface	20	5	15
Perform Image Motion Compensation	150	50	125
Assure Instrumentation Control	75	0	38
Provide Filtered Vehicle Rates and Attitudes	20	10	20
SUBTOTAL	265	65	198
TOTAL	1201	3763	4364

SPEED REQUIREMENTS

DATA PROCESSING

$$\text{Speed} = \frac{1.0 \times 10^6 \times 32^{(1)}}{16} = 2000 \text{ KAPS}$$

plus 15% overhead 300 KAPS

TOTAL REQUIREMENT 2300 KAPS

(1) Assuming 32 equivalent add operations per 16 bit data word in processing 1.0×10^6 bits per second.

CONTROL AND MONITORING

Speed = 265 x 1.5 = 0.398 KAPS

4.4.3.2 Ground Beacon Control - This technique will be selected by the experimenter to sense data upon response from a ground transmitted signal. This signal will emanate from the vicinity of the desired target. Data will be recorded only when the signal is received or the target is within the field-of-view of the sensor. During periods when the signal is either not transmitted or sighting of the target cannot be maintained, the data recording operation is halted. The sizing requirements for this technique are given in Table 4.4.3-2.

4.4.3.3 Fully Automated Data Take Controls - The purpose of this technique is to automatically gather data for a selected set of targets. Onboard navigation and control parameters will be obtained from the CDMS computer. Selected targets will be scheduled with sufficient lead-time to permit instrumentation warm-up and calibration. In the event that data gathering from scheduled targets is not possible, the CDMS will maintain a record of the targets and reschedule them at some later point in time. All data gathered in this automatic mode will be recorded on an ultra-high density tape. Data gathering may be scheduled in advance for up to 72 hours for an estimated 15 to 20 targets at approximately 15 seconds per target. Table 4.4.3-3 shows the sizing requirements for this technique.

4.4.3.4 Real Time "Quick Look" of Unscreened Channel Performance - This technique provides a timely scan of how well the system is performing by displaying scenes transmitted on manually selected channels. This "Quick Look" approach will enable the experimenter to make the earliest possible corrections to the data acquisition devices and/or preliminary processing algorithms. Display resolution is sufficient for evaluating system performance in this manner. The computer sizing requirements for this technique are presented in Table 4.4.3-4.

4.4.3.5 Post Data Pass - This technique will enable the experimenter to perform a detailed evaluation of the data that was recorded on the ultra-high density tape during the real time processing. Post-processing associated

Table 4.4.3-2 GROUND BEACON CONTROL

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Set Up to Begin Data Collection	12	6	12
Check Experiment Operational Status	6	2	5
Prep and Route Data to 120 MBPS UHD Tape	40	10	30
Check Target Alignment	40	10	30
Check If Display Required	6	2	5
Prep Data for 1.5 Mbit Auxiliary Storage	20	10	20
Prep Data for 6.0 Mbit Auxiliary Storage	30	10	25
Access 1.5 Mbit Auxiliary storage with MEDI Computer	20	3200*	3210
Prep Data for Display	60	20	50
Transmit Data to IOP D→A Converter, Process, Sync, Interlace & Display Video Data	150	256	331
Transmit Data via RAU to CDMS Computer and Display Alphanumeric Data	60	30	60
Standard Return Logic	20	0	10
SUBTOTAL	488	3576	3820

*Approximately 10 fetches per second assuming MEDI Computer has 16K of memory.

Table 4.4.3-2 GROUND BEACON CONTROL (Continued)

CONTROL AND MONITORING (ORBITER COMMUNICATIONS)

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Perform Image Motion Compensation	250	60	185
Assure Instrumentation Control	75	0	38
Provide If Required; Filtered Vehicle Rates and Attitudes	20	10	20
SUBTOTAL	345	70	243
TOTAL	833	3646	4063

SPEED REQUIREMENTS

DATA PROCESSING

$$\text{Speed} = \frac{1.0 \times 10^6 \times 16^{(1)}}{16} = 1000 \text{ KAPS}$$

plus 15% overhead 150 KAPS

TOTAL REQUIREMENT 1150 KAPS

(1) Assuming 16 equivalent add operations per 16 bit data word in processing 1.0×10^6 bits per second.

CONTROL AND MONITORING

Speed = 345 x 1.5 = 0.518 KAPS

with this technique involves making calculations and displaying the alphanumeric data on a CRT. If necessary, and at the experimenter's option, the calculations and displayed quantities should be updatable in an interactive fashion. Table 4.4.3-5 depicts the sizing requirements for the "post data pass" processing.

Table 4.4.3-3 FULLY AUTOMATED DATA TAKE CONTROLS

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Access and Process Vehicle Orbital Position and Uplinked Ground Target Coordinate Information	20	6	16
Schedule Upcoming Target	150	30	105
Assure Vehicle to Target Proximity	40	10	30
Maintain Target Track Log	30	5	20
Set Up to Begin Data Collection	12	6	12
Prep and Route Data to 120 MBPS UHD Tape	40	10	30
Check if Display Required	6	2	5
Check to See if Schedule Permits Powering Down Certain Equipment (Tapes, etc.)	20	5	15
Prep Data for 1.5 Mbit Auxiliary Storage	20	10	20
Prep Data for 6.0 Mbit Auxiliary Storage	30	10	25
Access 1.5 Mbit Auxiliary Storage with MEDI Computer	20	3200*	3210
Prep Data for Display	60	20	50
Transmit Data to IOP D $\longrightarrow$ A Converter, Process, Sync, Interlace & Display Video Data	150	256	331
Transmit Data via RAU to CDMS Computer and Display Alpha-numeric Data	60	30	60
Standard Return Logic	20	0	10
SUBTOTAL	702	3620	3971

*Approximately 10 fetches per second.

Table 4.4.3-3 FULLY AUTOMATED DATA TAKE CONTROLS (Continued)

CONTROL AND MONITORING (ORBITER COMMUNICATIONS)

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Perform Image Motion Compensation	300	50	200
Assure Instrumentation Control	50	20	45
Provide Filtered Vehicle Rates and Attitude as well as Navigation Inputs	20	10	20
SUBTOTAL	370	80	265
TOTAL	1072	3700	4236

SPEED REQUIREMENTS

DATA PROCESSING

$$\text{Speed} = \frac{1.0 \times 10^6 \times 24^{(1)}}{16} = 1500 \text{ KAPS}$$

plus 15% overhead 225 KAPS

TOTAL REQUIREMENT 1725 KAPS

(1) Assuming 24 equivalent add operations for each 16 bit data word in processing 1.0×10^6 bits per second.

CONTROL AND MONITORING

Speed = 370 x 1.5 = 0.555 KAPS

Table 4.4.3-4 REAL TIME "QUICK LOOK" OF UNSCREENED CHANNEL PERFORMANCE

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Select Channel of Interest	10	2	7
Set Up to Begin Data Collection for Selected Channel	12	6	12
Buffer Data for Single 20 MBPS Channel Using Micro-Processor #1 into Both 1.5 & 6.0 Mbit Auxiliary Storage Areas	50	20	45
Access 1.5 Mbit Auxiliary Storage with MEDI Computer	20	3200*	3210
Prep Data for Display	60	20	50
Transmit Data to IOP D→A Converter, Process, Sync, Interlace and Display Video Data	150	256	331
Transmit Data via RAU to CDMS Computer and Display Alpha-numeric Data	60	30	60
Check to See if Processing is Complete	6	2	5
Standard Return Logic	20	0	10
SUBTOTAL	412	3556	3762

*Approximately 10 fetches per second.

Table 4.4.3-4 REAL TIME "QUICK LOOK" OF UNSCREENED CHANNEL PERFORMANCE (Continued)

CONTROL AND MONITORING (ORBITER COMMUNICATIONS)

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Assure Instrumentation Control	75	0	38
SUBTOTAL	75	0	38
TOTAL	487	3556	3800

SPEED REQUIREMENTS

DATA PROCESSING

$$\text{Speed} = \frac{1.0 \times 10^6 \times 16}{16}^{(1)} = 1000 \text{ KAPS}$$

plus 15% overhead 150 KAPS

TOTAL REQUIREMENT 1150 KAPS

(1) Assuming 16 equivalent add operations per 16 bit data word in processing 1.0×10^6 bits per second.

CONTROL AND MONITORING

Not applicable for this technique.

Table 4.4.3-5 POST DATA PASS

STORAGE REQUIREMENTS

DATA PROCESSING

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Standard Linkage	24	20	32
Set Up to Access UHD Tape that was Created during Real Time Pass	12	6	12
Buffer Selected Data from Tape via Micro-Processor #1 into 1.5 and 6.0 Mbit Auxiliary Storage Areas	50	20	45
Access 1.5 Mbit Auxiliary Storage with MEDI Computer	20	3200*	3210
Prep Data and Perform Initial Calculations on Key Parameters	500	100	350
Prepare Data for Display	60	20	50
Transmit Data to IOP D $\longrightarrow$ A Converter, Process, Sync, Interlace and Display Video Data	150	256	331
Transmit Data via RAU to CDMS Computer and Display Key Parameters	60	30	60
Perform Updated Calculations	300	100	250
Display Updated Parameters	60	30	60
Provide Plot Capability on Image Data	400	120	320
Standard Return Logic	20	0	10
SUBTOTAL	1656	3902	7430

*Approximately 10 fetches per second.

Table 4.4.3-5 POST DATA PASS (Continued)

CONTROL AND MONITORING (ORBITER COMMUNICATIONS)

Functions	Instructions (16 Bit)	Data (32 Bit Wd)	Total Storage (32 Bit Wd)
Assure Instrumentation Control	100	20	70
SUBTOTAL	100	20	70
TOTAL	1756	3922	4800

SPEED REQUIREMENTS

DATA PROCESSING

$$\text{Speed} = \frac{1.0 \times 10^6 \times 32^{(1)}}{16} = 2000 \text{ KAPS}$$

plus 15% overhead	300 KAPS
TOTAL REQUIREMENTS	2300 KAPS

(1) Assuming 32 equivalent add operations per each 16 bit data word in processing 1.0×10^6 bits per second.

CONTROL AND MONITORING

$$\text{Speed} = 100 \times 1.5 = 0.150 \text{ KAPS}$$

4.5 OPERATIONAL PROCEDURES

The EO-06-S Integrated Interaction System provides for a means to reduce data quantity during scheduled and unscheduled data takes and it provides a means to obtain reasonable assurance as to quality of the data take in real time. The scheme provides also for the timeliest possible way to assess the data take short of ground site assessment (which by requirement is not intended and by the extremely high data rates not likely to occur).

4.5.1 Real Time Operation

In real time, the experiment operator may choose to engage the interactive system. Basically, five methods of interacting with the data are available. The desired method of interaction chosen by the experiment operator is selected by keyboard selection from the Payload Specialist Station (PSS).

Real time "Quick Look" for data collection systems performance is available for selection with or without additional automated real time screens. MSS spectral bands/channels may be selected one at a time and their respective real time data can be displayed as scene or image data by standard onboard TV. Data collection system performance may be monitored in this manner. Timely corrective action may be taken in the event of system malfunction or data degradation due to noise pollutants, etc.

The Spectral Condition Detection technique is selectable from the PSS when any given spectral condition prevalence is sufficient to determine whether the terrain under observation has the features desired rendering it, in turn, as "good" or "bad" data. This provides for rapid, automated ground data processing and also provides for a rapid scan and evaluation of data during the post data pass period. The technique may be manually terminated or timer "time-out" terminated.

The Ground Beacon Control of the data take is selectable from the PSS when ground track is anticipated to be in proximity of the beacon designated target. Since the beacon is directional, small but appropriate orbiter maneuvers (roll) may be expected to align the MSS line of sight with the beacon. The RECORD operation commences with signal alignment and ceases by manual control, timer "time-out" or loss of a signal.

The Fully Automated Data Take Controls is also a real time data quantity screen selectable from the PSS when a schedule of targets with coordinates are supplied from mission control. When this mode of data take control is selected all intended targets are scheduled and the data take is completely automated until manually terminated, timer "time-out" terminated or all scheduled targets have been observed. Targets not observed (system malfunction, etc.) are made available for rescheduling. Though not necessary, it seems desirable to use this screen in conjunction with the Spectral Condition Detection technique.

4.5.2 Post Data Pass Operation

For the Post Data Pass period of the orbit time is available to the experiment operator/scientific investigator to utilize for assessing in detail the data take effort, i.e., did the data gathering system perform correctly at all times, were all desired targets observed, are there incidentally acquired targets worthy of further investigation, are there any analysis techniques that can be applied to the data that has been collected? The Post Data Pass Screen when selected will provide for data tape read, scene display and interactive data analysis tools such as CRT plots and the simpler statistical and mathematical calculation routines.

4.6 COST/BENEFITS ANALYSIS

A groundrule that has been used in estimating hardware costs for the elements of the EO-06-S interaction system (all of which must be purchased) is that standard laboratory equipment (off-the-shelf equipment) can be utilized. This is concluded after assuming that the IGLOO can be used to house these elements during pallet mounted experiments. If pallet mounting is required due to insufficient IGLOO volume, then a factor relating standard laboratory equipment costs to space-qualified equipment must be applied to increase all affected cost estimates.

Table 4.6-1 lists the estimated cost for the 1980 time frame for the EO-06-S interaction equipment. All numbers are rough "order-of-magnitude" estimates only. Significant factors that are foreseen and that can influence these estimates are:

- Microprocessor #1 - Will be a new item for development and it will consist of a customer tailored IOP (Input/Output Processor) built around an off-the-shelf CPU.

- Microprocessor #2 - See previous item.

- MEDI Computer - Will be the latest state-of-the-art commercial computer with a 16K memory (an advanced PDP-11 for instance) with interrupt processing capability and standard I/O modules being assumed.

- Auxiliary Storage Device - Cost projections for this device are based on present bubble memory and CCD (Charge Coupled Device) technologies of 0.02¢ per bit. For the 7.5 Mbit storage requirement, an additional $50,000 development cost has been

assumed for each storage module (one 1.5 Mbit and one 6.0 Mbit). Development costs would be associated with any unique organization of the memory chips into desired input and output formats, packaging, etc.

Table 4.6-1 EO-06-S INTERACTION HARDWARE COST ESTIMATES

Item	Cost
Channel Selector	$25,000
Microprocessor #1	$250,000
Microprocessor #2	$160,000
MEDI Computer	$80,000
Auxiliary Storage Device	$101,500

Software cost estimates are listed in Table 4.6-2. Based on both Skylab and Saturn onboard and ground operations software a value of $20.00 per instruction is used. Each instruction is assumed to be 16 bits.

Table 4.6-2 EO-06-S SOFTWARE COST ESIMATES

Interactive Techniques	Instuctions	Total Cost
Spectral Condition Detection	1201	$24,020
Ground Beacon Control	833	16,660
Fully Automated Data Take Controls	1072	21,440
Real Time "Quick Look"	487	9,740
Post Data Pass	1756	35,120
TOTAL	5349	$106,980

Final savings estimates are based upon Skylab Earth Resources Principle Investigator (P.I.) quotes obtained from the Phase II fact finding trips. It was stated that fully 80% of all data obtained could have been eliminated as unnecessary by the interested, knowledgeable experiment operator when given the appropriate detection capabilities and means to exercise visual-judgmental faculties peculiar to the experimenter. Additionally, even valid data was found on occasion to be degraded by noise contamination, calibration source time changes, etc. This proportion of degraded data that must be corrected by extensive ground processing is assumed at 5% (minimum) to encompass actual data quality improvements obtained by interaction. A total of 85% data quantity reduction is foreseen as listed in Table 4.6-3.

Table 4.6-3 DATA QUANTITY REDUCTION

Technique	Data Quantity Reduction	
Spectral Condition Detection	40%	80%
Ground Beacon Control	5%	
Fully Automated Date Take Controls	35%	
Real Time "Quick Look"	3%	5%
Post Data Pass "Scan"	2%	
TOTAL	85%	

Interaction savings are realized from the 85% reduction in data to be processed. The quantity of data to be processed without interaction controls is computed at 3.35×10^{12} bits/mission (i.e., 0.41875×10^{12} bytes/mission). Total CPU time to process this data is based on the algorithm that uses 40 μsec CPU time to process each byte of data. CPU time computed to process 3.35×10^{12} bits is 4643 hours. CPU time when purchased to process the data is computed to be $1,216,466. Labor cost (minimum) is $46,430 for a

total processing cost estimate of $1,262,895. An 85% reduction therefore, in data processing costs saves $1,073,462 (minus the first time cost of the interaction hardware and software). Savings for the first flight is $1,073,462 minus $723,480 or $349,982. Savings for the second and subsequent flights are $1,073,462 per flight. Additional savings that are less quantifiable but, nevertheless, just as valid, are to be anticipated for reduction in tape storage facilities, tape costs and data archiving. A savings is also anticipated in the area of increased scientific data value. This can be based on data 'freshness' obtained from quicker total data evaluation that is made possible by reduced data processing time. A more subtle and also non-quantifiable benefit is that derived from improved mission productivity through the visual tools made available to the experimenter to assess each data take in such a manner as to permit a data retake, etc., before the mission has terminated (the cost or the possibility of a reflight has not been evaluated).

5. STUDY RESULTS AND CONCLUSIONS

Spacelab User Interaction Study results and conclusions from the SO-01-S and EO-06-S interaction systems development study point solidly to the profitability in terms of scientific value and dollars of this means of effecting a reduction in data quantity and an improvement in data quality.

The SO-01-S and EO-06-S payloads have been utilized as typical, interaction amenable payloads suitable, ultimately, for actual demonstration of the value of the interaction systems proposed.

The Solar Physics and Earth Resources communities in the areas of investigation and sensor development have been interviewed to access their unique relevant experience. Their suggestions were factored in with other basic inputs to the Phase II study. From the Phase II development of a number of payload applicable interaction techniques, an integrated interaction system for each of the two payloads has been developed by the Phase III study. The SO-01-S and EO-06-S Integrated Interaction Systems have been functionally defined and are accompanied with corresponding hardware block flow diagrams, hardware specifications, software sizing and speed requirements, operational procedures and finally cost/benefits analysis data for both onboard and ground based system elements. The cost/benefits analysis for SO-01-S and EO-06-S show that accrued benefits, dollar-wise, are attributable to a reduction in data processing costs obtained by, generally, a considerable reduction in the quantity of data that might otherwise be generated without interaction. Reduced data processing costs include reduced CPU time, CPU operations personnel, and data storage, turnaround and archiving as savings areas. Cost benefits were justified in two areas of savings only; namely, CPU time and CPU operational personnel because of the easily quantifiable nature of these two areas and their sufficiency to monetarily justify the need for interaction.

Detailed analysis of the SO-01-S payload which can generate 6.0×10^{12} bits per 7-day mission substantiates a data quantity reduction of 55%. This translates into a savings of 4583 hours of CPU processing time and 4583 hours of CPU operational personnel time valued at $1,245,000. This benefit to be obtained on each 7-day mission for SO-01-S is offset by a one time cost of $612,720 to implement the interaction system into the payload.

In similar manner analysis of the EO-06-S payload which can generate 3.35×10^{12} bits per 7-day mission, substantiates a data quantity reduction of 85%. A data quantity reduction of 85% translates into a savings of 3947 hours of CPU processing time and 3947 hours of CPU operations personnel time which is valued at $1,073,462. This benefit is repeated for each 7-day mission for EO-06-S. The benefit is offset by a one time cost of $723,480 to implement the interaction system into the payload.

There are other additional savings anticipated, but which are not easily monetarily measured such as increased scientific value obtained by the quicker return of all useful data that is made possible by the reduced time to process the data from a mission, i.e., the positive value of data 'freshness' has not been quantified. For both payloads, there is also a very positive benefit in improved productivity for the mission that is realized through the visual tools made available to the experimenter enabling him to see his targets in the non-visible spectrum. These tools, for earth resource payloads, will also enable the experimenter to schedule data retakes etc. before the mission is terminated if a scheduled target was not adequately scanned for any reason. Again, benefits have not been quantified for saving the cost of a possible reflight.

In conclusion, the results of the Spacelab User Interaction Study have produced a compendium of good techniques (Phase II) for two typical Spacelab payloads. From the techniques, an integrated interaction system has been

developed that when analyzed from a cost versus benefit viewpoint, yields good evidence capable of justifying the benefits of interaction. The evidence generated by this study is sufficient to demonstrate that at this point in the Shuttle era a continuing effort to investigate, generalize and demonstrate interaction for payloads other than EO-06-S and SO-01-S within the Solar Physics and Earth Resources disciplines should be pursured. Extension to other disciplines that are interaction amenable must also be considered.

6. CONSIDERATIONS FOR FUTURE STUDY

Phase III of the Spacelab User Interaction Study concludes that interaction is a beneficial, even necessary, requirement for two Spacelab payloads, SO-01-S and EO-06-S. The study work product (i.e., integrated system definition, design, hardware specifications, software requirements and operations procedures) and cost/benefits analysis strongly recommend a continuation of such activity as would lead ultimately to implementation.

Interaction, logically, should be directed into the area of preparation for demonstration, demonstration being necessary to validate the interaction concepts prior to onboard and ground system implementation and integration.

Follow on that is recommended should include all of those items detailed for future work to follow Phase III that were set forth in the Phase II report. They were:

- Utilize the current study results and generate an interaction demonstration plan. The task would define a systems plan to validate the interaction concepts and to include the associated demonstration.

- Broaden the scope of the baseline interaction systems to include all payloads within the respective disciplines.

- Perform compatibility analysis studies to design an interaction system for multi-discipline payloads and examine the baseline interaction systems for necessary modifications to generate a distinct system applicable to all of the Spacelab experiment disciplines.

- Integrate the final interaction system into the total Spacelab data flow performing an investigation to determine the impacts on the Spacelab subsystems resulting from implementation of the interaction system. It is desirable to perform this effort in such a manner as to benefit from any time delays necessary to perform the other tasks of the follow on work. This would permit Spacelab experiment and subsystem definitions to evolve significantly along with a final principle investigator designation for each experiment. Certain pacing items are foreseen as requiring additional time to mature prior to a final integration and implementation effort.